Preface

Application of the Ventilated Improved Pit (VIP) latrines on massive scale in future sanitation programmes in Developing Countries is most likely. Therefore, a research on the ventilation aspects of this sanitation system was necessary.

Tha main conclusion of this report: " The VIP latrine, a ventilation study" is that, with regard to ventilation efficiency, the VIP latrine functions properly as long as there is wind blowing over the top of the vent-pipe.
Depending on the wind velocity, ventilation volumes ($m^3/s$) can reach significant values.
Details on the ventilation pipe as diameter, length etc. can be found in Chapter 5, Conclusions.

Chapter 2 deals with theoretical background material, while the other chapters reveal information on the field research.
The field research is executed at the Building Research Unit (BRU) in Dar es Salaam, Tanzania.
The literature study, evaluation and report-writing took place in Delft, The Netherlands.

Acknowledgement

I would like to express my sincere gratitude to the following people for their contribution and cooperation in realizing this research, wich is a part of my MSc study, Civil Engineering, division of sanitary engineering at Delft, University of Technology (DUT) The Netherlands.

| | |
|---|---|
| Prof. dr.ing. H.J. Pöpel | Supervisor, Dept. of Civil Engineering, Division of sanitary engineering, DUT. |
| Ir.Dick C. van Ginhoven | Act. Head of department of Public Health Engineering, Ardhi-Inst. Dar es Salaam. |
| Mr. R.A. Boydell | Advisor to the LCSU Low Cost Sanitation Unit, Ardhi-Ministry, Dar es Salaam. |
| Mr.D. Baker | Gauff Ingenieure, Consulting Engineers Dar es Salaam. |
| Ir. H. van Oorschot | Dept. of Mathematics, DUT |
| Ir. R. Veldkamp | Sanitary Eng., dept of Civil Eng. DUT |

Furthermore I would like to thank staff and students of the dept. of Public Health Engineering, Ardhi-Inst. DSM, for their hospitality and friendship.

Peter Heeres

Sept. 1981 - Aug. 1982
tutorial assistent
Dept. of PHE/Ardhi - Inst.
Dar es Salaam / Tanzania

Adress :
Spoorsingel 61
2613 BA DELFT
The Netherlands

Contents

List of figures

List of tables

List of appendices

## Introduction

The ministry of Lands, Housing and Urban Development of the United Republic of Tanzania in cooperation with Gauff Ingenieure, consulting engineers/Dar es Salaam, is working on the Buguruni squatter upgrading programme. The Buguruni area is in Ilala District within Dar es Salaam region,Tanzania.

A component of the Buguruni project is the construction of VIP (Ventilated Improved Pit) latrines.
Experience from other VIP latrines in Dar es Salaam indicated that VIP latrines ventilate reasonably.
In order to find the magnitude of this ventilation and the influence of some parameters, this ventilation research was set up.
The effect of for example wind speed on ventilation of a VIP latrine is not predictable, due to too many different aspects (wind direction, slope of the roof, environment, etc.), a field study was therefore necessary.
The field study is executed at the BRU (Building Research Unit) in Dar es Salaam, where for this purpose an experimental VIP latrine was built.

This report deals with the measurements on this VIP latrine at the BRU.
A literature study has been undertaken, in Delft/The Netherlands, to support the field measurement.
The over-all conclusions can be found in chapter 5.

## Chapter 1 Ventilation Studies

### 1.1 Introduction

The Ventilated Improved Pit-latrine (abbreviated by VIP) is a serious option as a low-cost sanitation method. This simple excreta disposal system differs from conventional pit latrines in the way it's constructed.
A conventional pit latrine is sometimes not more than a dug pit or an oil-drum in the ground, covered f.i. with planks to facilitate squatting. The fence can be made of wooden poles with in between palm- or bananaleaves or gunny sacks.
The VIP latrine differs from the conventional pit latrine by having a vent-pipe, a more solid way to construct the pit, squatting slab and superstructure.
The most striking detail of the VIP latrine is the vent-pipe, wich generates a strong updraft and so maintains a flow of air down through the squatting plate. The effect of this air current is to minimize odours and to discourage fly breeding within the pit; moreover, if the exit of the vent-pipe is covered with a mesh and the latrine superstructure is kept relatively dark compared to the pit ( or the squat plate covered) any flies wich do hatch out in the pit will be attracted to the daylight at the top of the vent-pipe, where they will be trapped by the mesh and eventually die.

The VIP latrine technology is identified by the World Bank on technical, social and financial grounds as a realistic option for sanitation.
Several types of ventilated improved pit latrines have been developed. In the series of the World Bank of 'Appropriate Technology for Water Supply and Sanitation' some types of VIP latrines are described.

Fig. 1.1 A simple pit latrine in rural Kenya A latrine of this sort may be quite acceptable for many years but tends to become smelly and to attract flies It may be improved by adding ventilation . (Photo R G. Feachem)

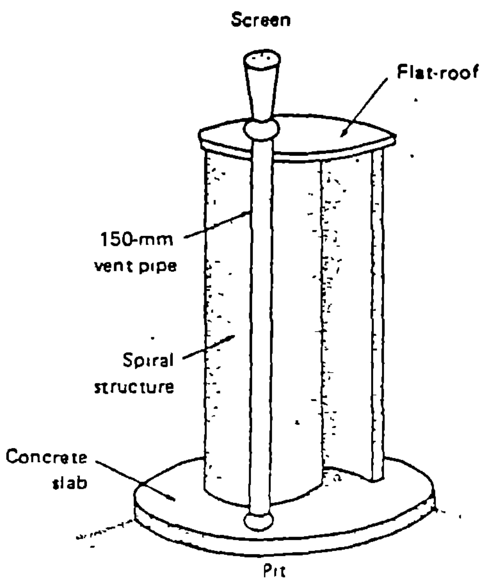



Fig. 1.2 ventilated pit privy, as used in Zimbabwe

## 1.2 Goals of the research

Pilot projects, as there was the Dar es Salaam demonstration project, revealed that the majority of the VIP latrines do ventilate satisfactorily.
The questions put forward in this research are:

- What is the magnitude of the ventilation ?
- What kind of factors have an influence on ventilation ?
- How much influence has each factor on ventilation ?

The results of this research should give design guidelines for a VIP latrine reference to ventilation.

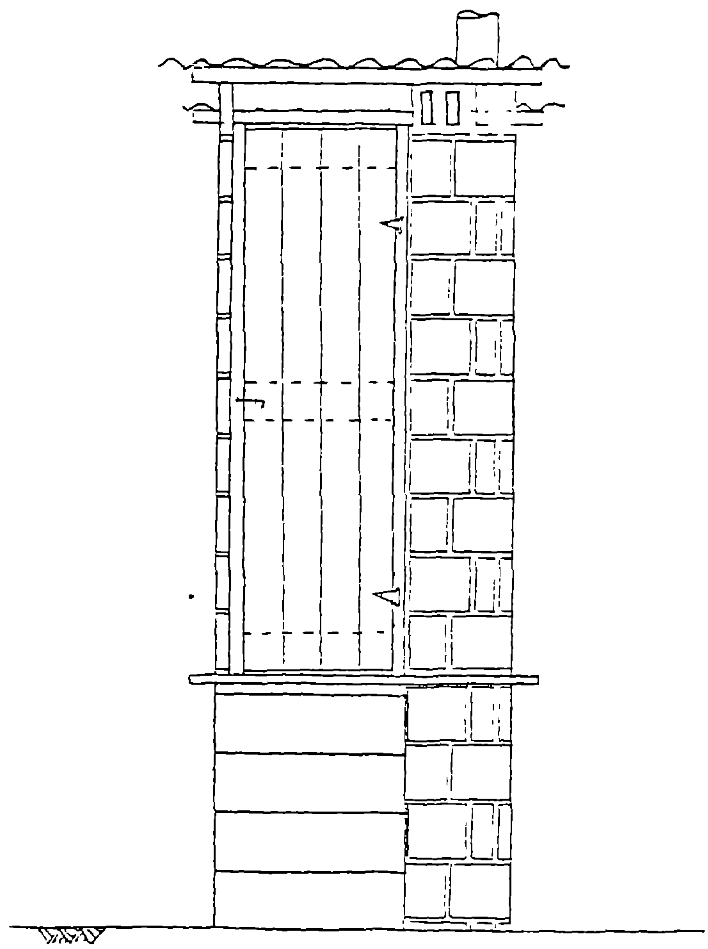


Fig. 1.3 Frontside of the VIP latrine built at the Building Research Unit in Dar es Salaam, Tanzania.

Most of the VIP latrines in Dar es Salaam are elevated, due to the high ground-water table.

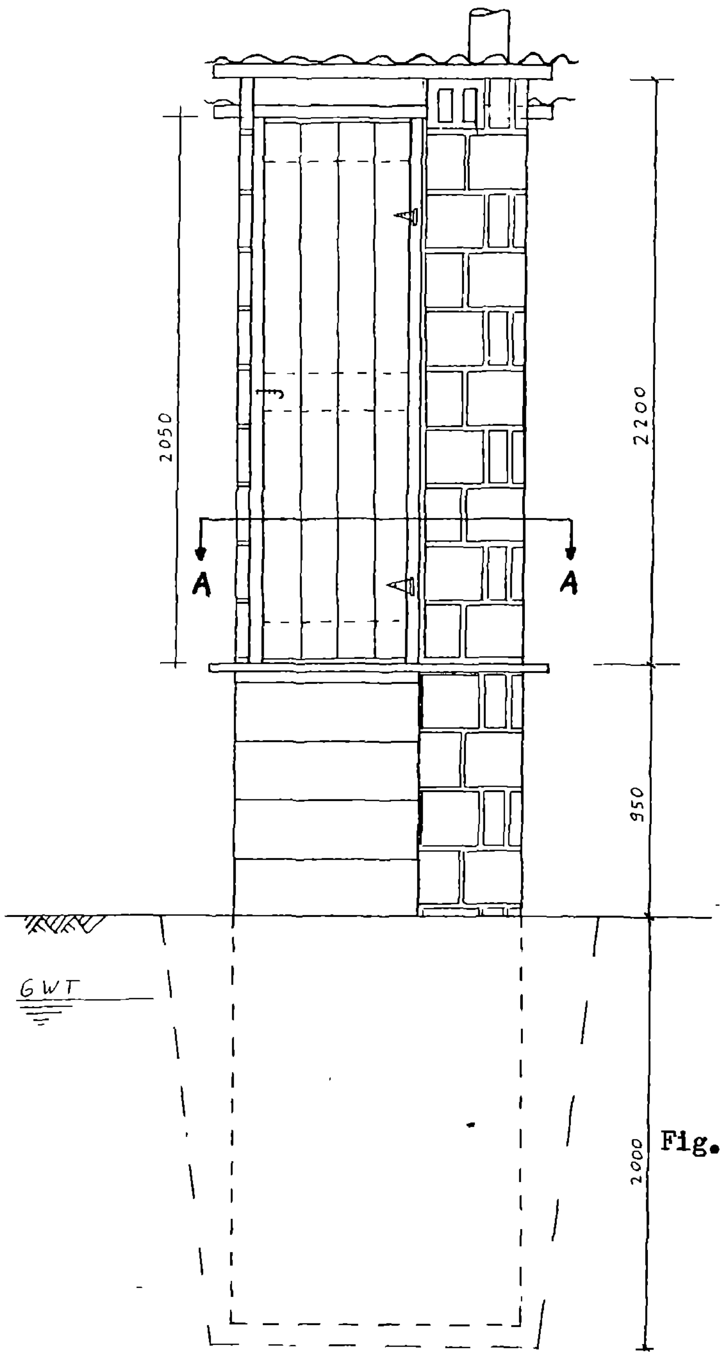
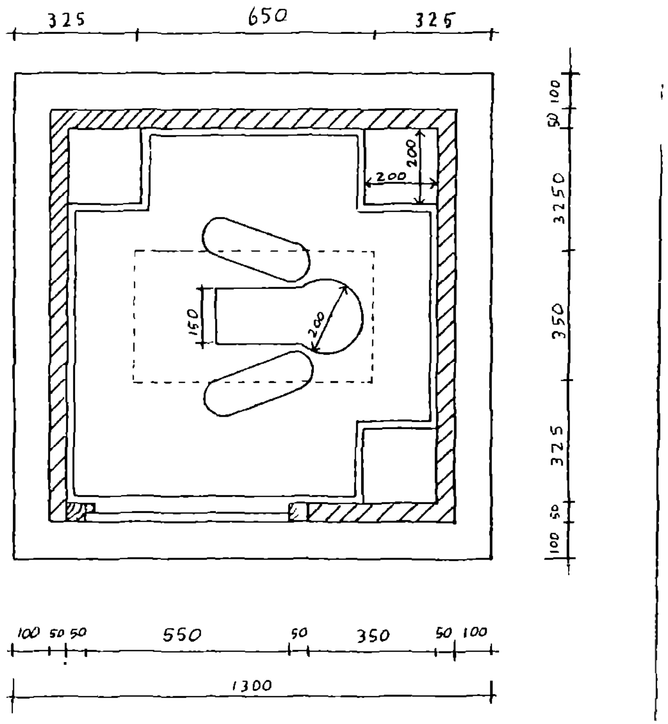



Fig. 1.4 Frontside of VIP latrine




Sand/cement wall

Fig. 1.5 Cross-section A-A, showing squatting slab

## 1.3 Ventilation

### 1.3.1 Definition

Ventilation is defined as the circulation of fresh air. Natural ventilation is ventilation wich is the result of the influence of wind/or the influence of a difference in temperature between air outside and air inside.

The purpose of ventilation is to minimize odours and thus to increase the comfort of the latrine.
The two main sources of odours are: -the pit content
-excreta fouling the squatting slab.
A proper maintenance (cleaning regularly of the squatting slab) should prevent the second source.
The first mentioned source should be kept to a minimum by f.i. a contineous air flow trough the key-hole in the squatting slab into the pit or by keeping a cover on the key-hole.

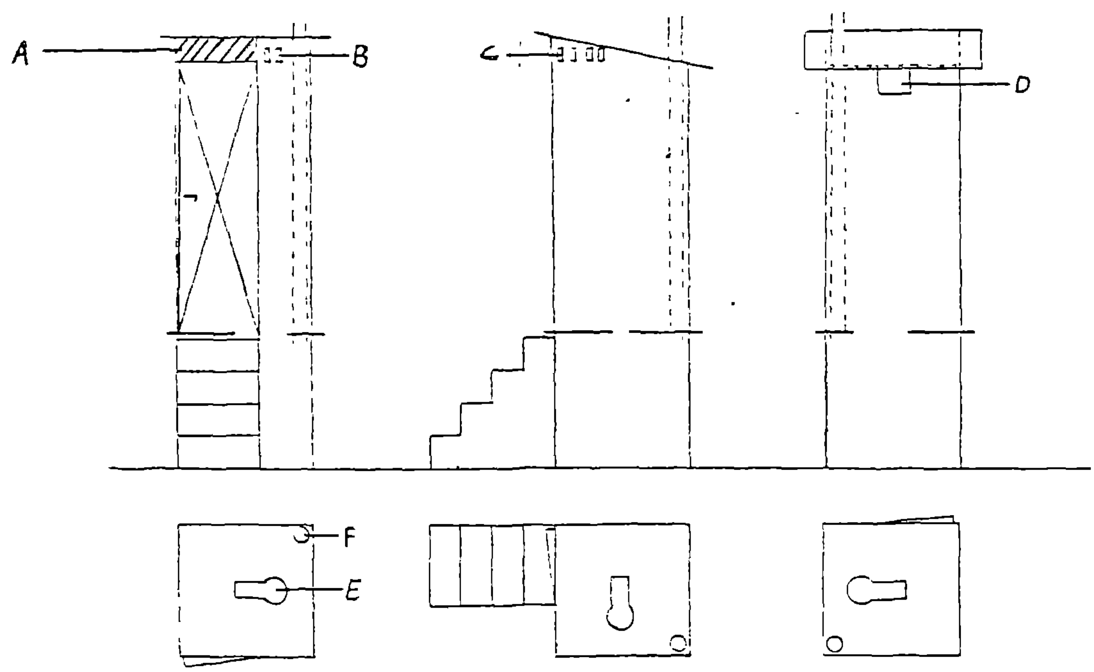



Fig. 1.6 Ventilation openings on test latrine

Openings, important to ventilation. ( VIP latrine, BRU )

| | | |
|---|---|---|
| A | Front side, above door | 1100 $cm^2$ |
| B | Two small openings | 80 $cm^2$ |
| C | Side walls (each) | 160 $cm^2$ |
| D | Back side | 440 $cm^2$ |
| E | Key hole | 655 $cm^2$ |
| F | Ventilation pipe | diameter 10,15, 20 cm |

Table 1.1 Ventilation openings on test latrine.

### 1.3.2 Types of flows

Two ventilation flows can be defined :

a: Cross-ventilation: By cross ventilation I mean, a flow of air entering and leaving the superstructure through ventilation openings in the walls of the superstructure. The magnitude of this ventilation flow is not measured at the test latrine.

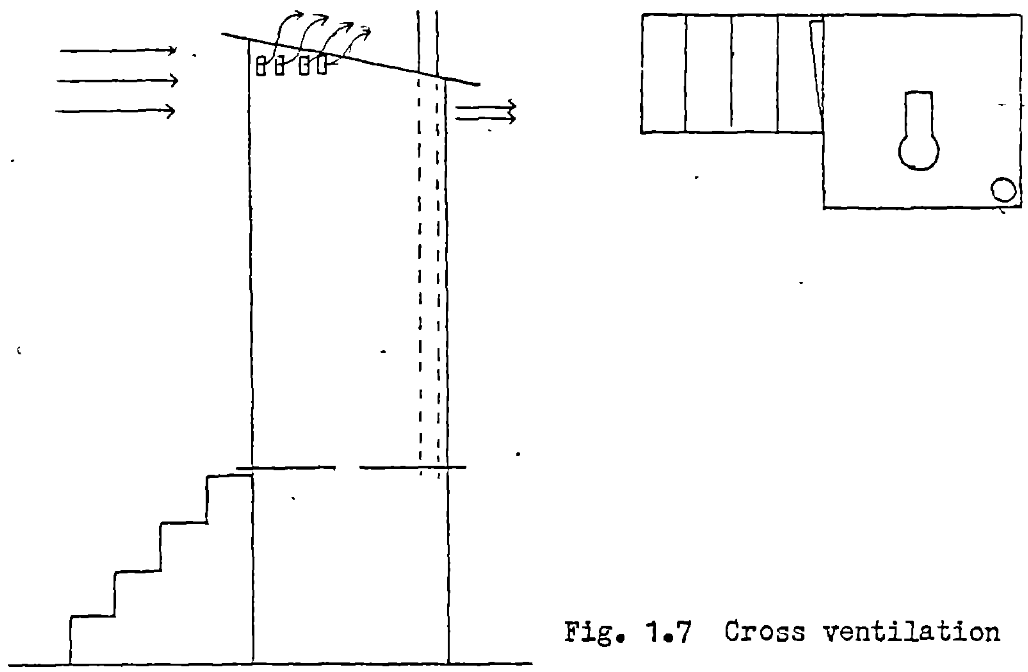


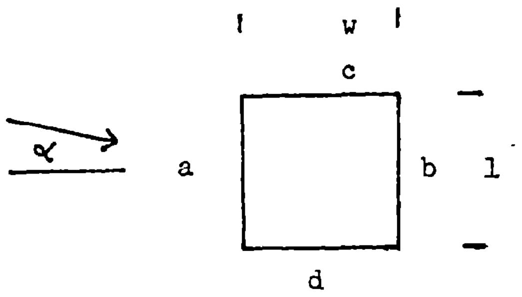
Fig. 1.7 Cross ventilation

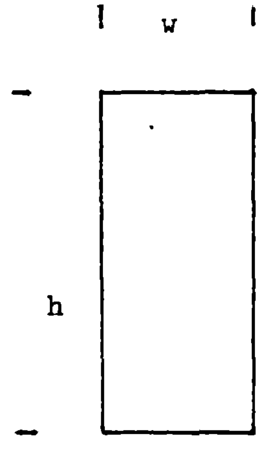
This type of ventilation depends on :

a - wind ( velocity, direction)

b - design superstructure (position and flow characteristics of all openings, construction superstructure)

British Standards gives for a construction as the VIP latrine for the distribution of pressure at the surface. (Cp)




Height ratio $\frac{h}{v} = \frac{3.2}{1.1} = 2.9$

Plan ratio $\frac{l}{w} = 1$

| α | Cp for surface | | | |
|---|---|---|---|---|
| | A | B | C | D |
| 0 | 0.8 | 0.25 | 0.8 | 0.8 |
| 90 | 0.8 | 0.8 | 0.8 | 0.25 |

Table 1.2 Coefficient of pressure at the surface

Ventilation volume: $Q_w\ (m^3/s) = C \times (Cp)^{\frac{1}{2}}$

C depends on wind velocity/ventilation openings.

**b: Pit-ventilation:** Pit ventilation occurs when a flow of air is entering the pit through the key-hole, passes through the pit and leaves the pit through the vent-pipe. Wind blowing over the top of the vent-pipe creates an underpressure by wich ventilation is induced. A chimney works according the same principle.

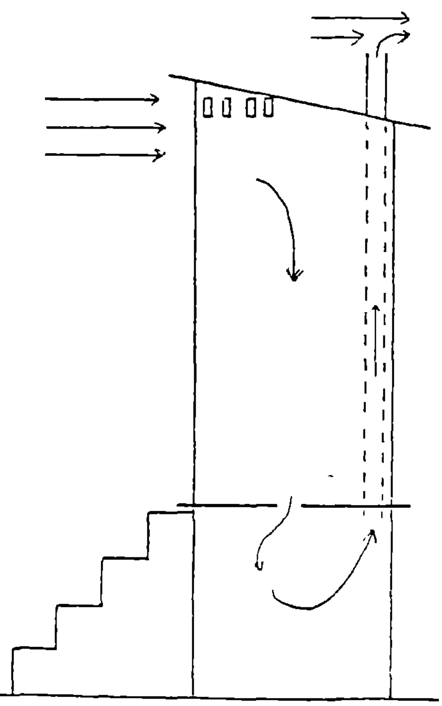


Fig. 1.8

Pit ventilation

### 1.3.3 Factors influencing ventilation

Factors wich might influence the ventilation to more or less extent are listed here under.

1. wind velocity
2. wind direction
3. angle of the wind, compared to horizontal, in relation to the top of the vent-pipe
4. diameter vent-pipe
5. diameter top vent-pipe
6. length vent-pipe
7. height top vent-pipe to roof
8. location of the vent-pipe inside the latrine
9. mosquito gauze on top of the vent-pipe
10. a cover on the squatting plate
11. ventilation/light openings in the superstructure
12. weather conditions, other than wind
13. surface roughness of the vent-pipe
14. location of the latrine in relation to the surroundings
15. design superstructure

Not all factors are discussed in detail in this report. Only with the direct results of the measurements will be dealt here.

The advantage of the experimental VIP latrine at the BRU was that some parameters could be monitored.
The following parameters :

- diameter vent-pipe
- height vent-pipe above the roof/ length vent-pipe
- the use of enlargers/diameter top vent-pipe
- location of the vent-pipe inside the latrine
- mosquito gauze
- cover
- door open/closed

Later on in this report, the influence of above mentioned parameters on wind velocity/ventilation velocity relation will be discussed.

## 1.4 Standards

In order to get an idea of how much ventilation, calculated as ($m^3/h$) of fresh air flowing through the vent-pipe, is required some standards from several countries are put together.

| | | |
|---|---|---|
| The Netherlands | (1) | NEN 1087 |
| United Kingdom | (2) | BS 5925 |
| India | (3) | IS 3362 |
| Australia | (4) | AS 1668 |
| (IHVE Guide) | (5) | |

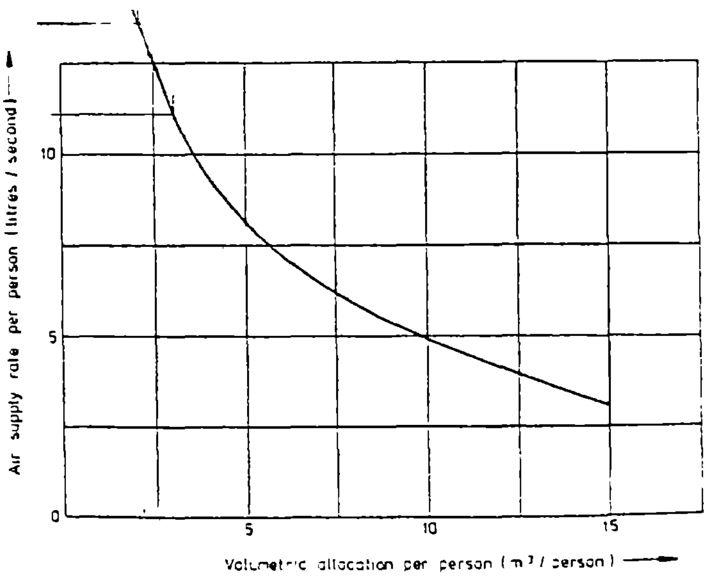
1. The Netherlands

| | | |
|---|---|---|
| living room | 0.021 - 0.042 | $m^3/s$ (75 - 150 $m^3/h$ ) |
| other rooms | 0.001 | $m^3/s$ per $m^2$ floorarea with a minimum of |
| | 0.007 | $m^3/s$ (3.6 $m^3/h$ per $m^2$ floor area) |
| bathroom | 0.014 | $m^3/s$ (50 $m^3/h$) |
| Water Closet | 0.007 | $m^3/s$ (25 $m^3/h$) |

2.United Kingdom

See fig. 1.9 Air supply rate for odour removal.

This figure gives as required ventilation for a room with a volume of 3.3 $m^3$ the number of 11.1 litres/second (40 $m^3/h$)




Air supply rate for odour removal

Fig. 1.9

3. India

| | |
|---|---|
| Living room and bed room | Three changes per hour should be provided |
| Bathroom and W.C. | Three air changes per hour should be provided |

4. Australia

| | | |
|---|---|---|
| General living area, bedrooms | Minimum fresh air requirement per person | 2.5 L/s |
| Kitchen | | 10 L/s |
| Bath, Toilet room | | 10 L/s |

5.IHVE Guide

Table B 2.2 Mechanical ventilation rates for various types of buildings, lavatories and toilets, internal 6-8 recommended air change rates ( $h^{-1}$)

The standard for latrines are based on, a: inside toilet
b: water-closet

The Dutch and Indian standards do mention that the standard for a W.C. is based on the idea that considerable ventilation after use is desirable.
With a pit latrine we should not only consider that there will be an unpleasant odour after use, but secondly also of a smell from inside the pit wich might enter the superstructure through the key-hole. To get rid of this nuisance a large but especially contineous flow of air through the vent-pipe is preferable.

Calculation example

| | | |
|---|---|---|
| A VIP latrine | floor area | 1 $m^2$ |
| | height | 2.1 m |
| | volume VIP | 2.1 $m^3$ |

Standards in $m^3/h$

| | |
|---|---|
| 1 | 25 $m^3/h$ |
| 2 figure gives 12.24 L/s | 44 |
| 3 three times 2.1 | 6.3 |
| 4 10 Litres per second | 36 |
| 5 eight times 2.1 | 16.8 |

When we transfer the standards to the minimum required ventilation velocities for different vent-pipes, than we get the following values.

| | | | | |
|---|---|---|---|---|
| Diameter (inch) | | 4 | 6 | 8 |
| ( cm ) | | 10.16 | 15.24 | 20.32 |
| Area cross-section ($cm^2$) | | 81.07 | 182.41 | 324.29 |
| Standard m. | | | | |
| 1 | 25 $m^3/h$ | 0.86 m/s | 0.38 | 0.21 |
| 2 | 44 " | 1.51 | 0.67 | 0.38 |
| 3 | 6.3 " | 0.22 | 0.10 | 0.05 |
| 4 | 36 " | 1.23 | 0.55 | 0.31 |
| 5 | 16.8 " | 0.58 | 0.26 | 0.14 |

Table: 1.3 Minimum ventilation velocities, according different standards for a 4", 6" and 8" vent-pipe.

# Chapter 2 Theoretical background

## 2.1 Introduction

The principal of natural ventilation is old. However information on the type of ventilation, mentioned in chapter 1.2.3 as pit ventilation, typically for VIP latrines is hard to find. The literature referred to in this chapter originates from 1932 to 1958.

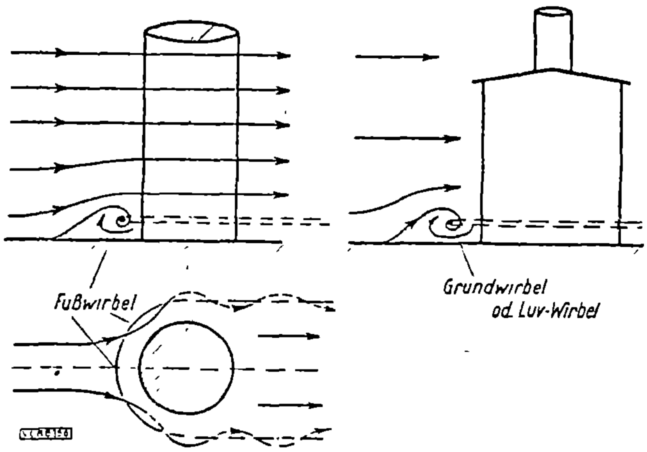
Subjects dealt with in this chapter are :

- the principle of creating draught in a pipe by wind.
- Influence of wind velocity and -gradient on draught in a pipe.
- losses in flow due to friction and mosquito gauze.
- The last sub-chapter deals with the influence of sun radiation on ventilation on a type of VIP latrine, as built at the BRU. A 24 hour measurement of temperatures in and outside the latrine is used as basis for this chapter.

Unfortunately no information is found on the influence of pipe diameter on draught.

## 2.2 Secundary flow

Secundary flow is flow induced by a main flow. Examples of secundary flow are shown in fig. 2.1 and fig. 2.2.
The main flow (horizontal) approaching the pipe over the full lenght induces two types of secundary flows.




Fußwirbelbildungen

Fig. 2.1 Ground-whirle.

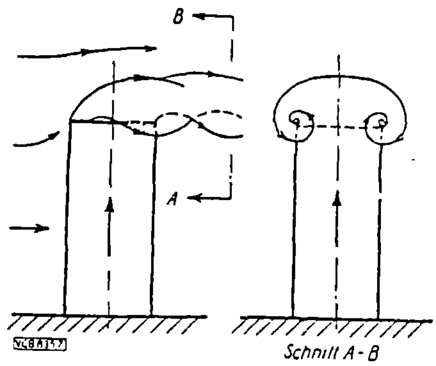



Fig. 2.2 eddies, on top-pipe.

I A ground-whirle near the basis, fig.2.1, is created because the main flow encounters near the ground some resistance. This whirle plits up in two ways around the obstacle, one to the left and one to the right. These two whirles will continue in the direction of the flow as two small spiral-like whirles. You can notice a ground-whirle as a draught near/in front of big buildings or mountains. Ref. 18 mentions this mechanism in reference to roofs of high buildings, especially on wich chimneys are located.

II At the free end (top) of the pipe, two eddies (fig. 2.2) are induced by the main flow, wind.
At the same time a strong draught and flow (vertically) is created in the pipe by this effect.

Pressure- and velocity measurements, in a research by H.Föttinger, show a relation between the statical underpressure $\Delta$ p in a chimney divided by the wind-pressure and the flow velocity in the pipe divided by wind velocity.
This relation, fig. 2.3, shows that the underpressure dropps, initially quickly and later on slowly, to zero with increassing flow velocity when the in- and outside velocities equalize.
Characteristics of the chimney are unfortunately not mentioned in this report ( ref. 19).

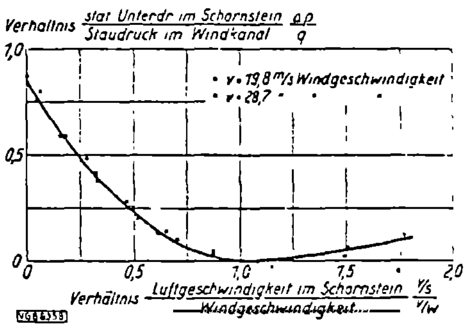



Fig. 2.3 Draught in a chimney

## 2.3 Windtunnel experiments on several types of chimney caps, influence of wind gradient.

In the Netherlands many types of chimney caps have been developed. In order to compare several types of chimney caps, wind tunnel experiments have been undertaken. (The Hague 1938, Gasstichting) Ref. 16)

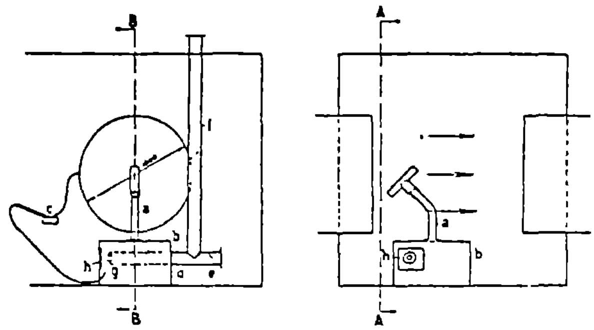


Fig. 2.4

View A-A Cross-section B-B

Installation in windtunnel

The study finds a linear relation between :

I : Wind velocity (Vw) and ventilation velocity (Vv)

II : Wind pressure Pw and underpressure $\Delta$ p, measured by manometer c.

From the 34 types of chimney caps tested, the five shown in fig. 2.5 are of interest to us.

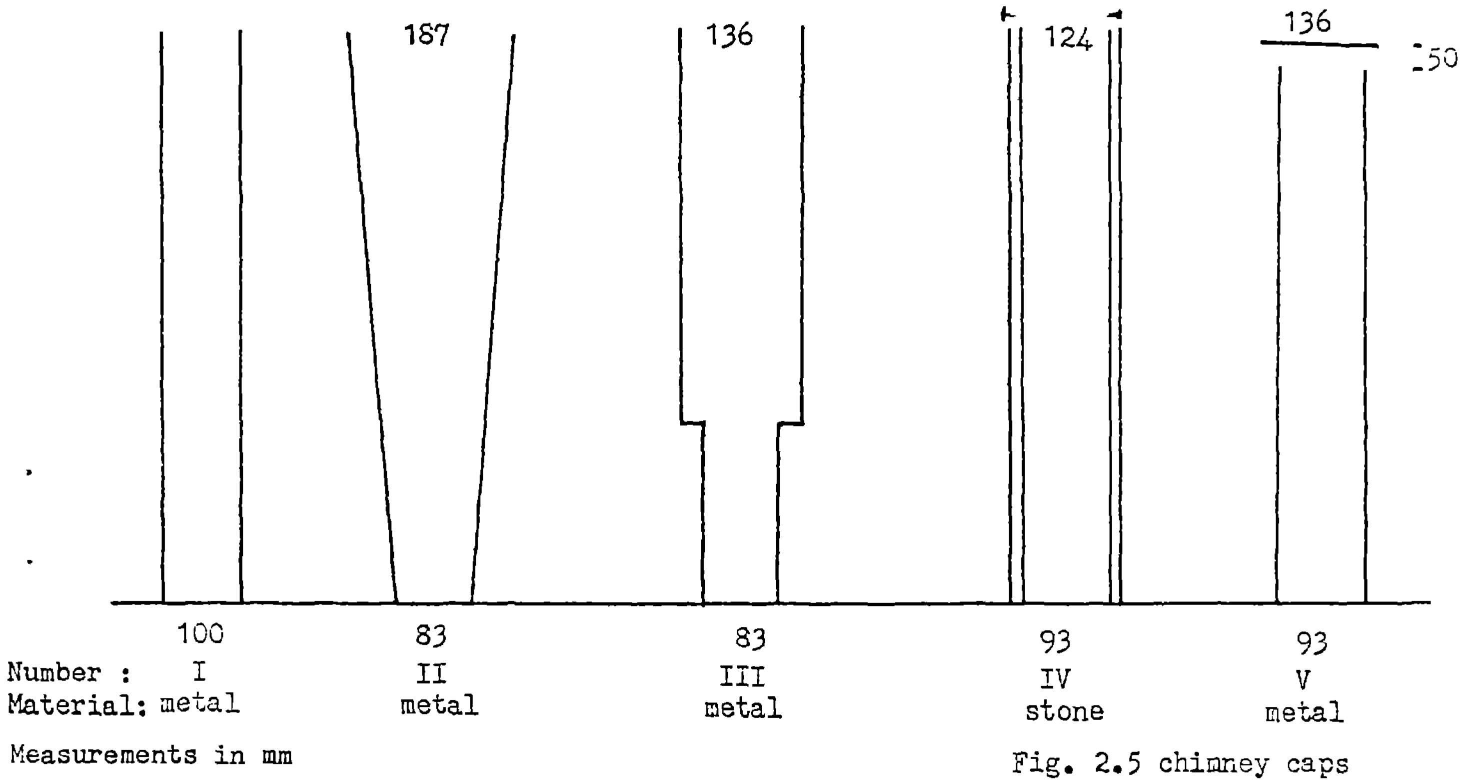



Fig. 2.5 chimney caps

The wind gradient has an influence on ventilation efficiency, as can be noticed in table 2.1. The table shows some of the results from the research done in 1938.

Table 2.1: Average value of $\Delta p/Ps$ see fig. 2.4, (Vv=0; wind
velocities: 2.6
5.7
and 11.2 m/s)

| Chimney cap | ↓+90 | +↘45 | →0 | ↗-45 | ↑-90 |
|---|---|---|---|---|---|
| | | | wind gradient | | |
| V | 0.42 | 0.68 | 0.96 | 0.11 | -0.52 |
| I | -0.92 | -0.80 | 0.87 | 0.47 | 0.17 |
| II | | | 0.82 | | |
| III | | | 0.80 | | |
| IV | | | 0.92 | | |

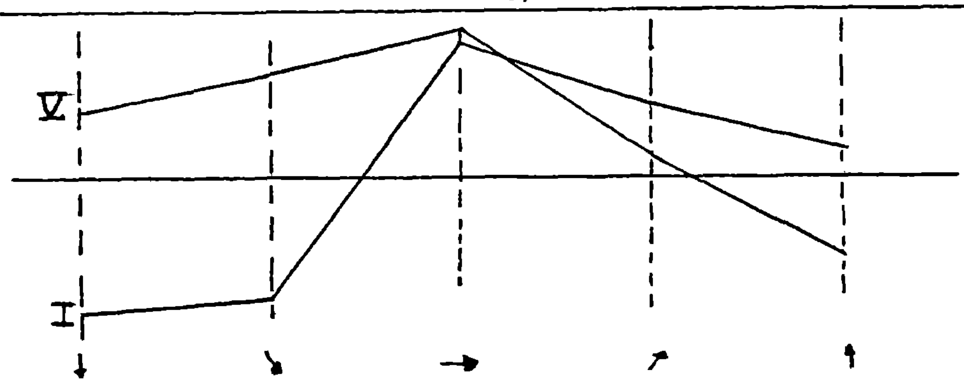



Fig. 2.6 Representation of table 2.1

Chimney caps type II, III and IV show a similar behaviour as type I.

From table and figure can be concluded that for horizontal wind the draught will reach an optimum. (Ref 17 gives $-5/-10^{\circ}$ as gradient as optimum).

Positive gradients will reduce ventilation efficiency very quickly. When the gradient exceeds $+24^{\circ}$, due to wind blowing into the top of the pipe an over-pressure is created, the difference in pressure will become negative.

## 2.4 Losses in flow

### 2.4.1 Pipes

The head loss due to friction may best be determined by the use of a rational formula:

$$H = \frac{2\ f\ l\ v^2}{g\ d_i} \qquad (1)$$

where

| | |
|---|---|
| H = Head lost, metres of fluid flowing | (m) |
| f = Coefficient of friction (fig. 2.7) | (-) |
| l = Lenght of pipe | (m) |
| v = Velocity of air flow in vent-pipe | (m/s) |
| g = Acceleration due to gravity | ($m/s^2$) |
| $d_i$ = Internal diameter of vent-pipe | (m) |

The pressure loss per unit lenght of pipe (specific pressure loss) is given by :

$$\Delta p = \frac{\Delta P}{l} = \frac{H \rho g}{l} \qquad (2)$$

where

| | |
|---|---|
| $\Delta P$ = Pressure loss | ($N/m^2$) |
| $\Delta p$ = Pressure loss per metre run of pipe | ($N/m^3$) |
| $\rho$ = Density of fluid flowing | ($kg/m^3$) |

Combination of 1 and 2 gives

$$\Delta p = \frac{2\ f\ v^2 \rho}{d} \qquad (3)$$

The coefficient of friction f, is a variable dependent upon:

a. the physical characteristics of the fluid flowing, the velocity of flow and the internal diameter of the pipe, wich three components mey be combined for consideration in terms of Reynolds Number, a dimensionless quantity:

$$(Re) = \frac{v\ d \rho}{\mu} = \frac{v\ d}{\nu} \qquad (4)$$

where

| | |
|---|---|
| (Re) = Reynolds Number | |
| $\rho$ = Density of fluid | ($kg/m^3$) |
| $\mu$ = Absolute viscosity of fluid | (kg/ms) |
| $\nu$ = Kinematic viscosity of fluid | ($m^2/s$) |

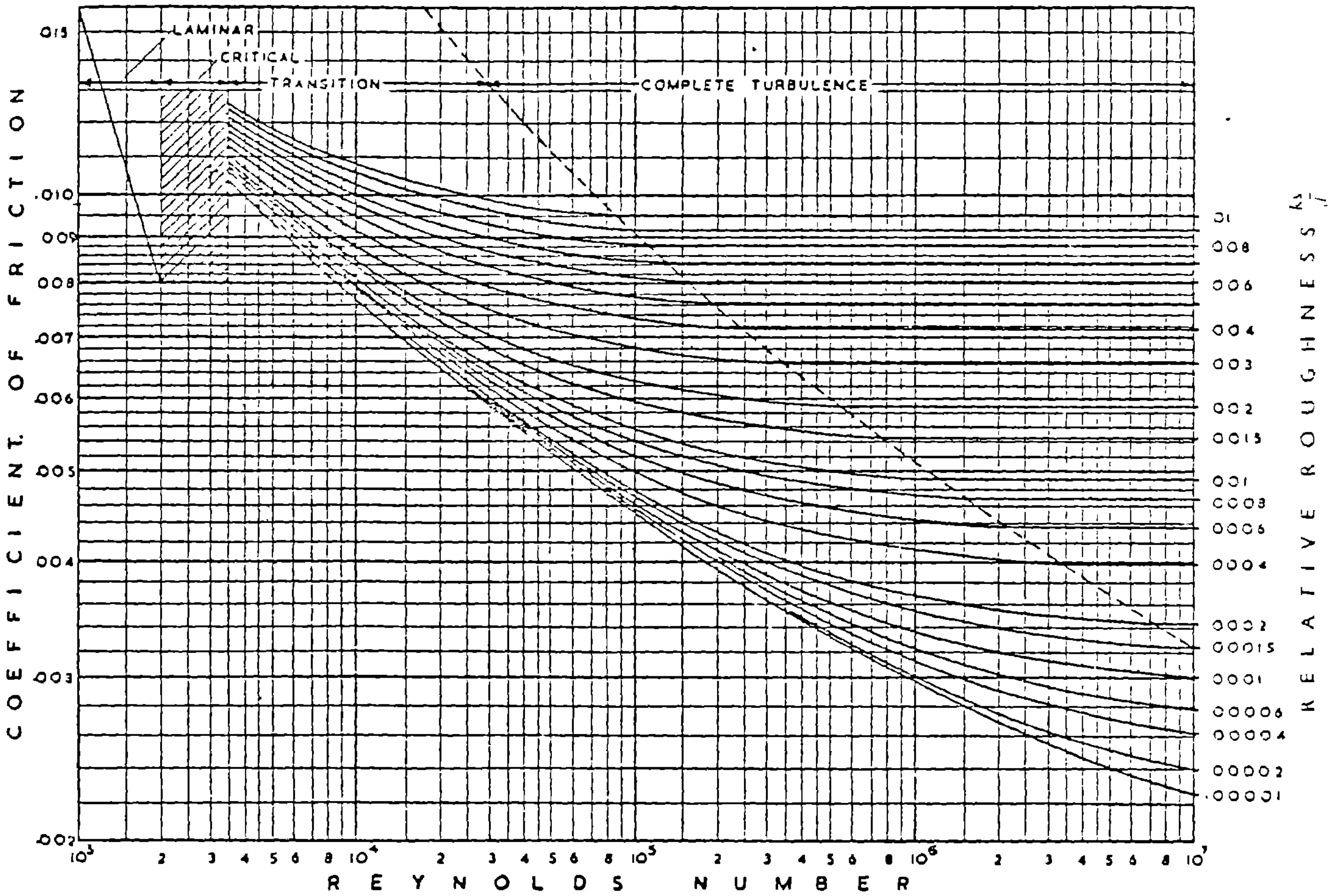



Fig. Relationship between roughness, friction and Reynolds Number

Fig.2.7

b. The roughness of the pipe wall relative to the internal diameter, wich is expressed in terms of a dimensionless ratio, $k_s/d$, where $k_s$ is a lineal measure of absolute roughnes having the same dimensional units as the diameter.

The relation between the coefficient of friction f and these components involves the use of the following expression:

(Re)<2000

Here flow is streamline or laminar in charecter, the roughness of the pipe walls is not a significant factor and the coefficient of friction may be calculated from the formula of Poiseuille:

$$f = \frac{16}{(Re)} \qquad (5)$$

(Re)>3000

Here flow is turbulent and all the components prevously discussed have value. The formula of Colebrook and White has now been generally accepted as being the best theoretical apprcach :

$$\frac{1}{\sqrt{f}} = -4 \log_{10} \left( \frac{k_s}{3.7\, d} + \frac{1.255}{(Re)\sqrt{f}} \right) \qquad (6)$$

### 2.4.2 Mosquito gauze

The head loss due to mosquito gauze can be represented by the non-dimensional loss coefficient $\lambda = \Delta Pt / \frac{1}{2} \rho v^2$
where: $\Delta Pt$ is loss in pressure due to mosquito gauze/V= velocity of air flow in vent-pipe.

Knowing the characteristics of mosquito gauze :

$d_w$ diameter of the wire (m)

n1,n2 number of wires per linear meter in each direction, it is possible to calculate the air flow head loss through the mosquito gauze as follows (ref.19):

1) Calculate the fly screen porosity, a, from the equation:

$$a = (1 - d_w n1)\ (1 - d_w n2)$$

2) Calculate the modified mosquito gauze Reynolds Number, Rm, from the equation:

$$Rm = Re\ (d_w / d_i a)$$

where Re is the standard Reynolds Number of air flow in the vent-pipe and $d_i$ is the vent-pipe internal diameter (m).

3) Calculate the fly screen head loss coefficient, $\lambda$, from one of the empirical equations:

for $Rm \leq 20$:
$$\lambda = (33.93/Rm) \cdot ((1-a)/((1+a)a^{1.27}))$$

for $Rm > 40$:
$$\lambda = (6/Rm^{1/3}) \cdot ((1-a)/a^2)$$

Inter polation for $20 < Rm \leq 40$

$$\lambda = x + (Rm - 20) / (x - 4) / 20$$
$$x = (33.93\ (1-a)) / (20\ (1+a)\ a^{1.27})$$
$$y = (6(1-a)) / (3.4195 - a^2)$$

### 2.4.3 Calculation example, head loss
I due to friction
II due to mosquito gauze

The formulae required are described in chapter 2.4.1 and 2.4.2.

extra information;
$d_W = 0.25 \cdot 10^{-3}$ (m)
$n1 = 5.5 \cdot 10^2$
$n2 = 7 \cdot 10^2$
$a = 0.712$

$\rho = 1.17$ (kg/m$^3$) ( t=30°)
$\nu = 16.0 \cdot 10^{-6}$ (m$^2$/s)
$l = 2.80$ (m)
$k_s = 0.000015$ (m)
$g = 9.8066$ (m/s$^2$)

| | $d_i$= | 0.105 | 0.14 | 0.213 (m) |
|---|---|---|---|---|
| V = 0.5 m/s | | | | |
| | Re | 3281 | 4375 | 6655 |
| | l | 0.011 | 0.0098 | 0.0086 |
| | H | 0.0144 | 0.0099 | 0.0058 |
| I | ΔP | 0.1652 | 0.1136 | 0.0665 (N/m$^2$) |
| | Rm | 11 | 11 | 11 |
| | λ | 0.506 | 0.506 | 0.506 |
| II | ΔPt | 0.074 | 0.074 | 0.074 (N/m$^2$) |
| V = 1.0 m/s | | | | |
| | Re | 6562 | 8750 | 13312 |
| | f | 0.0087 | 0.008 | 0.0071 |
| | H | 0.0473 | 0.0328 | 0.0193 |
| I | ΔP | 0.5427 | 0.3763 | 0.2214 |
| | Rm | 22 | 22 | 22 |
| | λ | 0.404 | 0.04 | 0.04 |
| II | ΔPt | 0.236 | 0.236 | 0.236 |
| V = 2.0 m/s | | | | |
| | Re | 13125 | 17500 | 26625 |
| | f | 0.0071 | 0.0067 | 0.0061 |
| | H | 0.1566 | 0.110 | 0.652 |
| I | ΔP | 1.7968 | 1.2621 | 0.7481 |
| | Rm | 44 | 44 | 44 |
| | λ | 0.966 | 0.966 | 0.966 |
| II | ΔPt | 2.26 (N/m$^2$) | 2.26 | 2.26 |

Table 2.2 Head loss calculations

I friction :

- increasing diamter shows a reduction in pressure-loss
- increasing ventilation velocity results in an increasing pressure loss.

II mosquito gauze

- diameter has no influence on pressure loss ($N/mm^2$)
- ventilation velocity has a significant influence on pressure loss.

The high pressure loss with ventilation velocities above 1 (m/s) is however not of interest to us, because the minimum required ventilation velocity for the smallest diameter, 4" or 0.10 (m), is 0.86 (m/s) ( 4" - 0.86 ; 6" - 0.38 : 8" - 0.21 (m/s)).

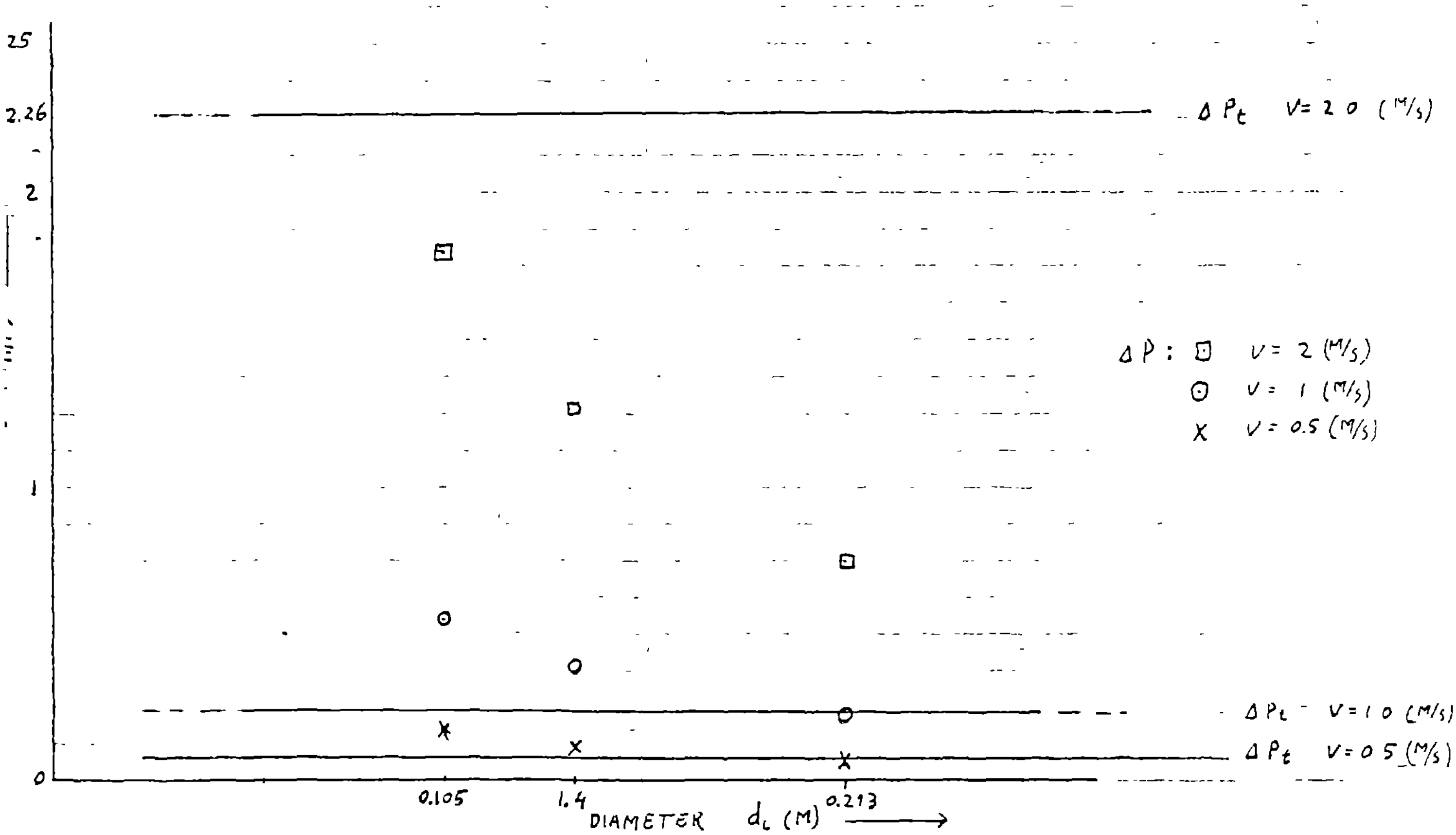



Fig. 2.8 Losses in flow
I ΔP due to friction
II $\Delta P_t$ due to mosquito gauze

## 2.5 Influence of Temperature on Ventilation

It is not difficult to realize that temperature, and to be specific a difference in temperature, will influence ventilation.
The density of air is different for different temperatures.
As we look at table 2.3 we see that f.i. the density at 0 °C is $\rho$ = 1.29 (kg/m$^3$) and for t is 30 °C $\rho$ = 1.17 (kg/m$^3$).

Table 2.3 Some properties of air

| Air \ Temp. °C | 0 | 10 | 20 | 30 | |
|---|---|---|---|---|---|
| $\rho$ (kg/m$^3$) | 1.29 | 1.25 | 1.21 | 1.17 | Density |
| $\nu$ ($10^{-6}$ m$^2$/s) | 13.3 | 14.2 | 15.1 | 16.0 | Kinematic viscosity |

The difference in temperature between the air inside the pit and the ambiant outside temperature causes a pressure.
Lüftungsanlagen im Wohnungsbau pp. 17 (ref.4) gives the following formula :

$$\Delta p = h\rho \frac{\Delta t}{273} \qquad (kg/m^2) \qquad (1)$$

$\Delta p$ = pressure arising (kg/m$^2$)
h = vertical distance between inlet and outlet openings (m)
$\Delta t$ = difference in temperature (°C)
$\rho$ = density (kg/m$^3$)

The IHVE Guide calles the influence of temperature "Stack Effect". Their equation for calculating the pressure in a building due to the inside/outside temperature difference is:

$$\Delta p = 3462\ h \left( \frac{1}{t_o + 273} - \frac{1}{t_i + 273} \right) \qquad (2)$$

$t_o$ = outside temperature (°C)
$t_i$ = inside temperature (°C)
$\Delta p$ = pressure arising (N/m$^2$)

This difference in pressure results in a ventilation velocity, if we forget flow-resistance, of

$$v = (2g \cdot p/\rho)^{\frac{1}{2}}$$

| | | |
|---|---|---|
| $v$ = | ventilation velocity | (m/s) |
| $p$ = | pressure calculated | ($kg/m^2$) |
| $g$ = | 9.814 | ($m/s^2$) |

Figure 2.9 shows the theoretical ventilation velocity due to difference in temperature for several shaft-heights, according formula (1).

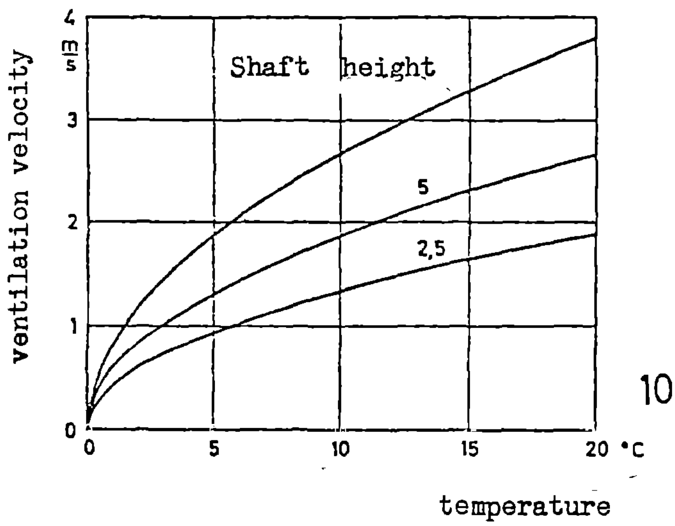



Fig. 2.9 Theoretical ventilation velocity, depending on difference in temperature and shaft height.

Calculation example.

In Dar es Salaam the temperature does not fluctuate very much during over 24 hours. The effect of day and night on temperature in and around a VIP latrine can be seen in fig. 2.10. (Measured on 20 Jan. 1982, Vip latrine Kiwilani/DSM, 6" vent-pipe).

| Hour | T3 | T6 | $\Delta T = (T_3 - T_6)$ |
|---|---|---|---|
| 08 AM | 29.2 | 28.3 | 0.9 |
| 10 " | 30.2 | 29.0 | 1.2 |
| 12 " | 31.9 | 29.9 | 2.0 |
| 02 PM | 33.0 | 31.1 | 1.9 |
| 04 " | 32.3 | 31.7 | 0.6 |
| 06 " | 31.8 | 31.2 | 0.6 |
| 08 " | 29.8 | 30.7 | 0.9 |
| 10 " | 29.2 | 30.0 | 0.8 |
| 12 " | 28.9 | 29.8 | 0.9 |
| 02 AM | 28.1 | 29.3 | 1.2 |
| 04 " | 27.8 | 28.8 | 1.0 |
| 06 " | 27.6 | 28.5 | 0.9 |

Table 2.3 : Temperatures over 24 hours in VIP latrine.

Temperature T6 : temperature inside pit
" " T3 : ambient outside temperature.

Both temperatures follow the same pattern during day and night. A positive (negative) effect on ventilation can be expected if $T3 > T6$ ($T3 < T6$)

$\Delta T$ ranges between + 2.0 and − 1.2

$\Delta T = +2; \Delta P\ (1)\ 0.236\ N/m^2\ \Delta P\ (2) = 0.210\ N/m^2$

$\Delta T = -1; \Delta P\ (1)\ -0.141\ N/m^2\ \Delta P\ (2) = -0.128\ N/m^2$

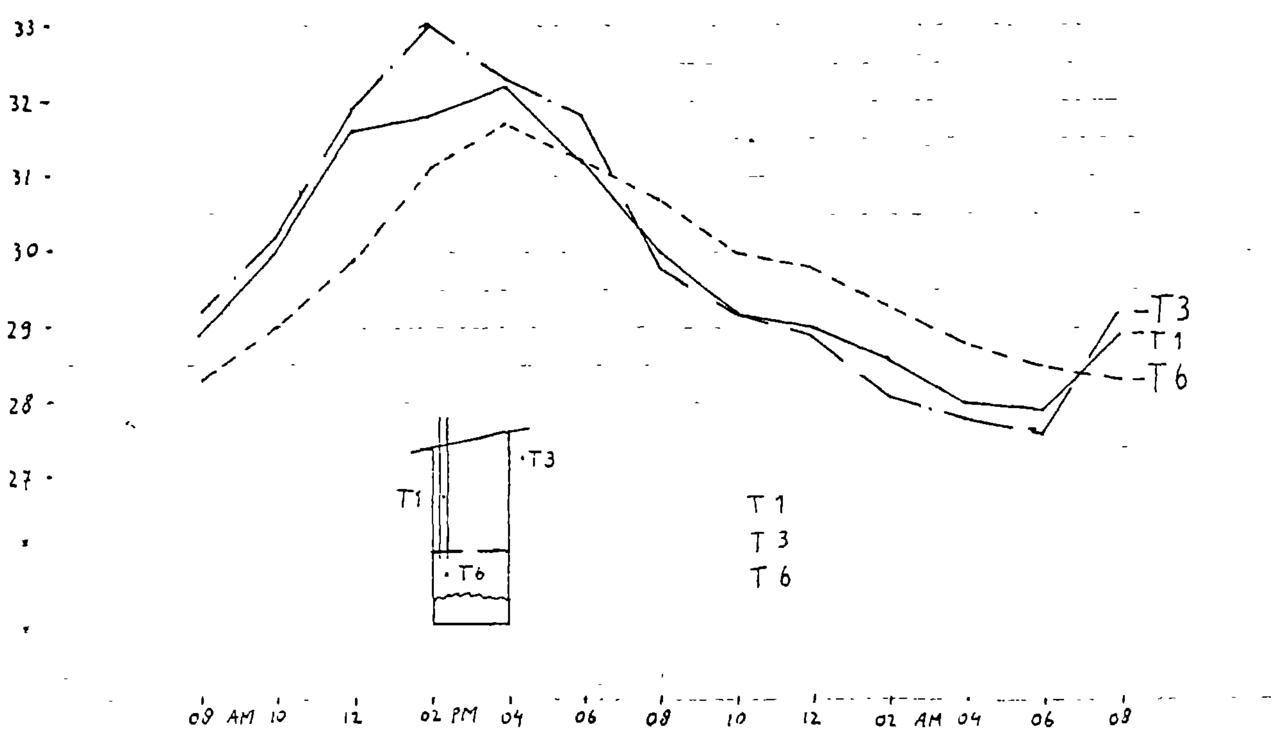



Fig. 2.10
Temperatures over 24 hours in VIP latrine (20 jan 1982 DSM/Tanzania)

## 2.6 Conclusions

The main conclusions are :

- There is a linear relation between draught and wind velocity.
- The draught will reach an optimum in velocity when the main flow, wind, is perpendicular in direction to the ventilation pipe.
- A positive wind gradient has a negative effect on ventilation efficiency, for a simple open vent-pipe. (fig. 2.6)
- The character of flow in a vent-pipe is turbulent.
- Flow resistance, due to mosquito gauze and friction of the pipe wall, depends much on flow velocity.
  The minimum ventilation velocities, less than 1 m/s, are not significantly reduced by flow losses.
- The effect of sun radiation can be either positive or negative, depending on the difference in temperature in- and outside the latrine. Due to the small difference in temperature, the effect is little. The advantage however is that the positive effect will occur during the night when wind velocity can be low.

## Chapter 3 Field Study

### 3.1 Introduction

The field study was executed in August 1982 at the Building Research Unit (BRU) in Dar es Salaam. Regarding the necessity of exchanging vent-pipes an experimental VIP latrine was built (Fig. 1.3;1.4;1.5 and 3.1). The measurements took place during day-time.
Appendix 3 gives exact information on weather conditions and day programme. This chapter deals with the test-site, equipment and test-programme.

### 3.2 Wind condition in Dar es Salaam

Because wind is essential for a VIP latrine, some information about the wind situation along the Tanzanian coast is given. Tanzania is experiencing the North-East trade winds from november to March and the South-East trade winds from april to october. The monsoon pattern is part of the global climate. This pattern is modified by the land masses. Thus, along the Tanzanian coast the sea breezes are modified. The diurnal pattern of sea-land breezes during day-time and to less extent, the land sea breezes during the night are distinct. This pattern reaches upto 8-10km inland, depending upon topography.
Late nights are often calm, during the mornings the sea-land breezes develop and at 10.00 AM wind speeds range between 3-5 m/s. The sea-land breeze reaches a peak in the mid-afternoon, when wind speeds decline towards the evening. Land-sea breezes start late in the evening and continue until dawn, with wind speeds much lower than during the day.

## 3.3 Description of the installation

### 3.3.1 VIP latrine at BRU

Figure 3.1 shows the latrine as built. It is a square latrine, inside 1 $m^2$, from wich the slab level is put on 0.95 m above the ground level because of the high ground water table. The vent-pipe is located inside. Ventilation openings (see fig. 1.6 and 3.2):

| | | |
|---|---|---|
| - Front side, above door | 1100 | $cm^2$ |
| - Two small openings | 80 | " |
| - Side walls (each) | 160 | " |
| - Back side | 440 | " |
| - Key-hole | 655 | " |

Walls and foundation :
Cement/sand stones, thickness of 5 cm.
Roof:
Sisal reinforced sheets

The VIP latrine stands relatively in the open. The wind can approach the VIP latrine from any side.
No trees or buildings are located in the near vicinity. The nearest building is the BRU building itself, on a distance of approximately 30 m..

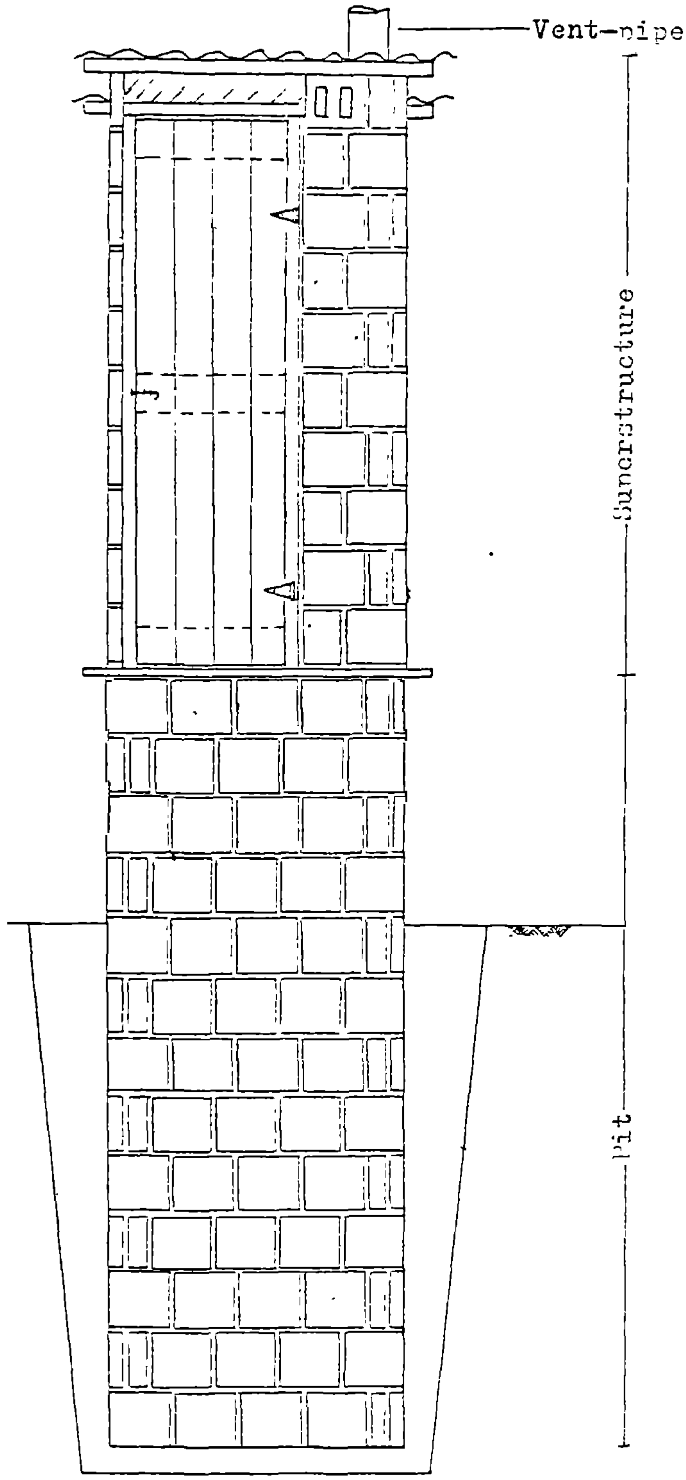



Fig. 3.1 Front side VIP latrine built at the BRU, Dar es Salaam, Tanzania.

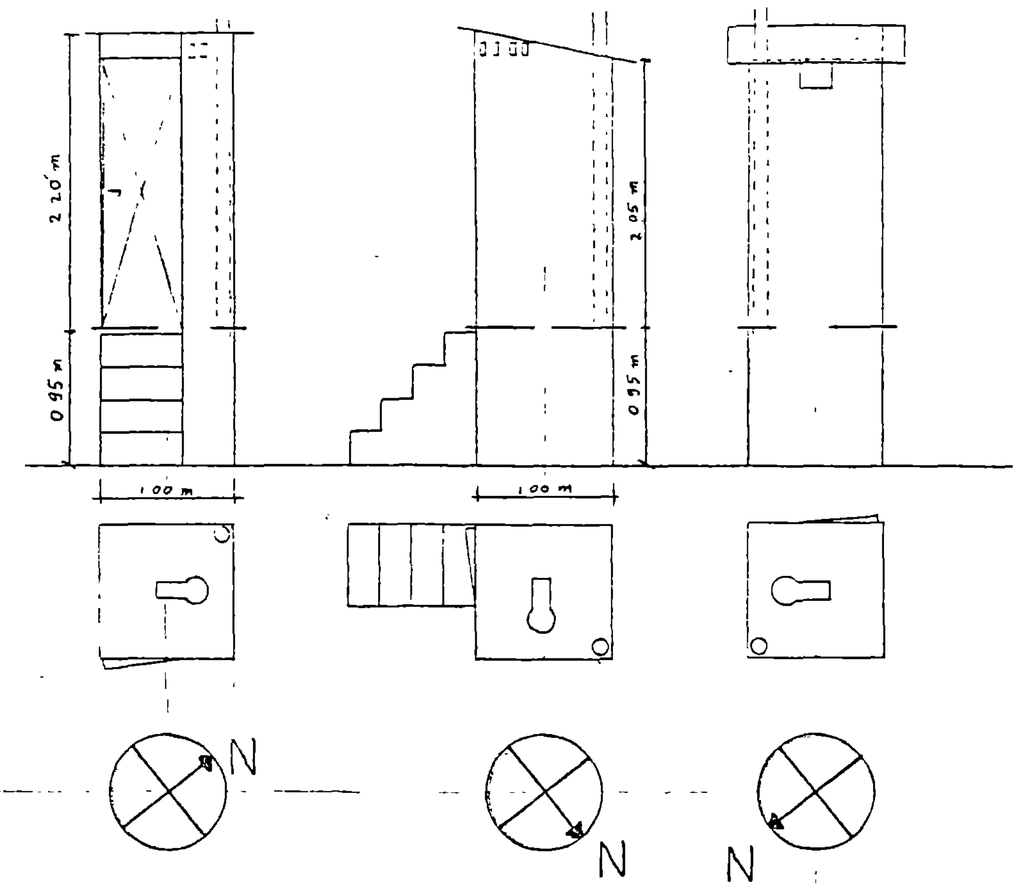
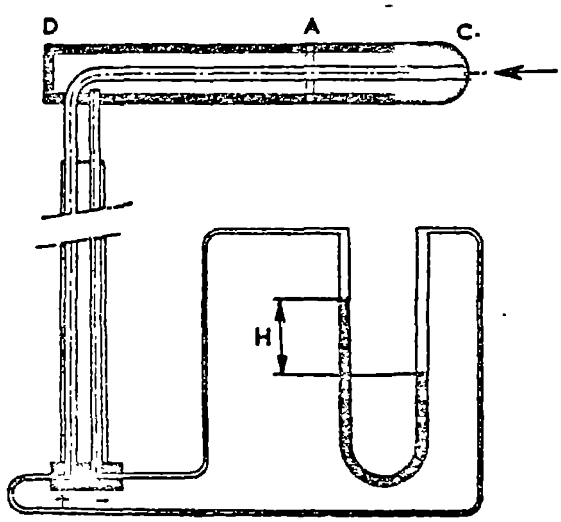



Fig. 3.2 Schematic drawing of VIP latrine, including North indication.

### 3.3.2 Equipment

In order to get an idea of the ventilation, the velocity of the flow of air going upwards in the vent-pipe is measured. Half-way the vent-pipe a pitot tube is fixed to the vent-pipe. The pitot tube is connected to a micromanometer. The ventilation velocity creates a difference in pressure. This difference in pressure is converted by the apparatus back to velocity (m/s) The velocity results are put on charts (chart speed 6 inch/h).

To find the wind velocity and direction nearby the top of the vent-pipe, an anemograph os located in the vincinity of the top of the vent-pipe.
Fig.3.5 shows the installation.
The anemograph consists of an anemometer and a windvane. The anemometer records the wind speed and the windvane records the wind direction. The results of the anemometer and the windvane are put on charts (chart speed 3 inch/h).




$H = \frac{1}{2} \cdot \rho \cdot V^2$

Fig. 3.3 Pitot-tube

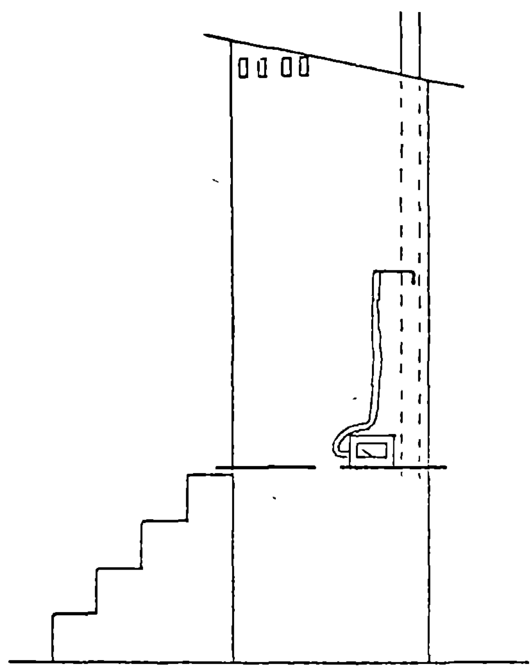


Fig.3.4 Location pitot-tube.

Fig. 3.5 VIP latrine at BRU, including anemograph.

Fig.3.6 View of front side, taken from the top of the VIP latrine. To the left, BRU building. To the right, a bakery.

## 3.4 Parameters selected

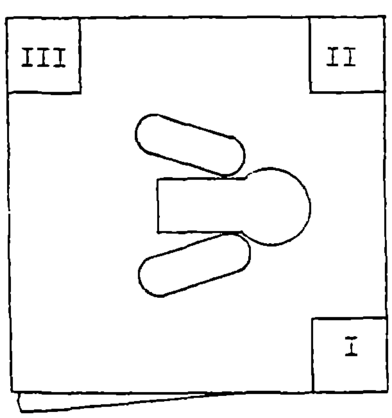
As mentioned in chapter 2 on factors influencing ventilation, the following are selected.

1. Diameter vent-pipe
The Dar es Salaam Demonstration project has installed VIP latrines with either 4 or 6 inches vent-pipes. Both types work reasonably, but the idea is that the 6" vent-pipe ventilates better.
The exact influence, if there is any, of diameter on ventilation velocity (m/s) induced by wind velocity is not known.
The reason for choosing three different diameters is the hope to find the optimum one within these differences. Chosen is for a 4", 6" and 8" vent-pipe. If the diameter has no influence on ventilation velocity, then there might be a significant influence of diameter on ventilation rate ($m^3/s$). On the other hand one should bare in mind, that especially for the very expensive PVC vent-pipe material costs increase significantly with increasing diameter.
The pipes used in the tests are made of PVC.

| Vent-pipe (inch) | Diam.(inside) (cm) | (Outside) (cm) | Thickness (cm) | cross-section ($cm^2$) |
|---|---|---|---|---|
| 4" | 10.5 | 11.0 | 0.25 | 86.6 |
| 6" | 14.0 | 16.0 | 1.00 | 153.9 |
| 8" | 21.3 | 22.7 | 0.70 | 56.3 |

Table 3.1 Information on vent-pipes used

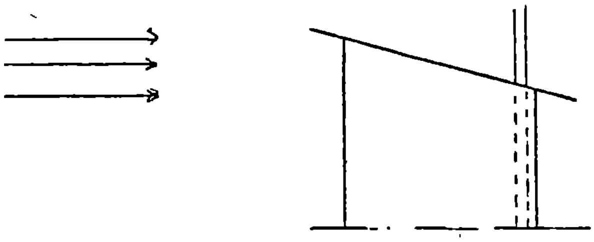
2. Location of the vent-pipe
The location of the vent-pipe in relation to the door, roof or squatting slab might have some influence (see parameter 3) Three positions are selected.




Possible locations for putting a vent-pipe.
Fig. 3.7

3. Height of the vent-pipe above the roof/length of the vent-pipe

Fig. 3.8 Top of VIP latrine.



The roof is built under a certain slope, to have rain directed backwards. It is possible that the wind near the top of the vent pipe doesn't move horizontally, but somehow under a certain angle, depending on wind direction and location of the vent-pipe. A short vent-pipe will experience more influence of the roof than a long vent-pipe.

Location I Length slab-roof 2.27 m.

Location II and III Length slab-roof 2.12 m.

| Pipe length (m) | Height roof-top vent-pipe Loc.I | Loc.II/III (m) |
|---|---|---|
| 2.40 | 0.13 | 0.28 |
| 2.55 | 0.28 | 0.43 |
| 2.80 | 0.53 | 0.68 |

Table 3.2 Relation between length, height roof-top and location of the vent-pipe.

4. The use of enlargers

An enlarger is a piece of the vent-pipe with a larger diameter as the vent-pipe from the slab upto the roof. An enlarger is put on top of the vent-pipe.

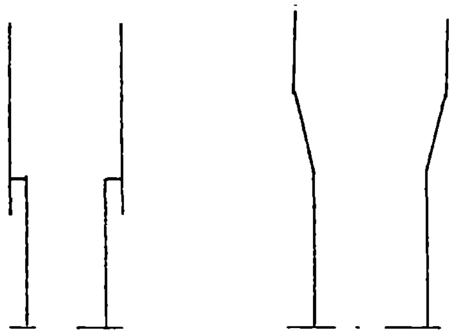
Ventilation is created by wind blowing over the top of the vent-pipe. There are two reasons to experiment with enlargers.

1. If only the top is important in creating ventilation, than it is possible that a 4" vent-pipe with a 6" enlarger will have the same result in $m^3/s$ as a 6" vent-pipe. An important reduction in material cost can be achieved.
2. When mosquito gauze is used, it will decrease the open area at the top, resulting in flow resistance. Increasing the diameter of the top of the vent-pipe will decrease flow resistance induced by the mosquito gauze.

Two combinations are tested :

- a 4" vent-pipe with a 6" enlarger and
- a 6" vent-pipe with a 8" enlarger

4" to 6"



6" to 8"

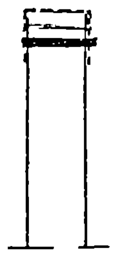
horizontal scale 1 : 10
vertical scale 1 : 20

Fig. 3.9 Enlargers

5. Mosquito gauze

The function of a vent-pipe is not only ventilation, but also to work as a fly-trap. Flies attracted by the light coming from the top of the vent-pipe, want to use the vent-pipe as exit. The way out through the vent-pipe can be blocked by mosquito gauze. It is logic that due to the mosquito gauze there will be a reduction in the ventilation velocity. (chapter 2.4)

Fig. 3.10
Mosquito gauze on
top of vent-pipe.

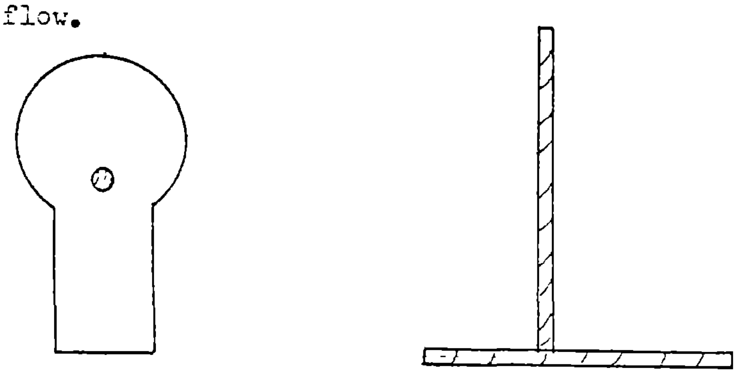


The mosquito gauze is put flat on top of the vent-pipe and fixed to it with an elastic.

6. Cover

A way to keep the pit dark and to prevent smell from the pit into the superstructure is by putting a cover on the key-hole. A disadvantage of using a cover is that it will be a significant barrier for air flow.

Fig. 3.11
Cover



7. Door open/closed

The VIP latrines built in the Unicef rural sanitation project in Iringa, Tanzania, are not equiped with doors, but L-shaped walls should guarantee privacy.

Although the VIP latrine at the BRU doesn't have a L-shaped wall, it seemed interesting what would be the result when the door is kept open during the measurements.

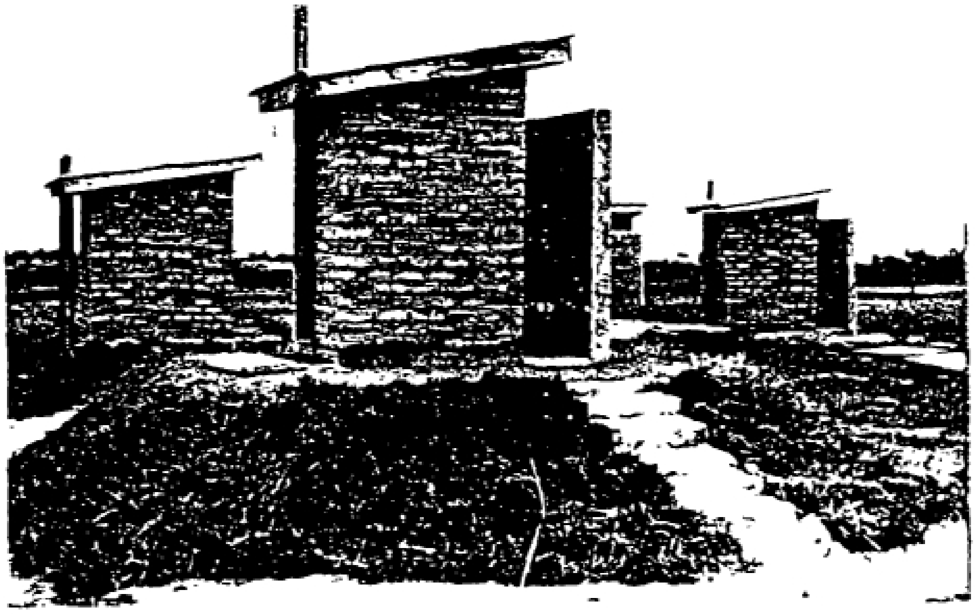


Fig. 3.12 Vip latrine equiped with L-shaped wall.
(Unicef rural sanitation project,Tanzania)

## 3.5 The test programme

Testing each alternative of the seven parameters would require 240 tests/measurements.

Parameter

| | | | |
|---|---|---|---|
| 1+4 | diameter | 5 | 4",4"+enl.6",6",<br>6"+enl.8",8". |
| 2 | location vent-pipe | 3 | I,II and III |
| 3 | length vent-pipe | 3 | 2.40m, 2.55m, 2.80m |
| 5 | mosquito gauze | 2 | yes/no |
| 6 | cover | 2 | yes/no |
| 7 | door open | 2 | yes/no |

The most important parameters considered, before starting the measurements, were diameter and mosquito gauze.
The 6" vent-pipe is chosen as reference diameter. The alternatives of parameter 2,3,6 and 7 are carried out with a 6" vent-pipe.
Measurements with mosquito gauze are executed for one position and on the longest vent-pipe. The idea is that the longest vent-pipe length will evince no influence of position.
Therefore is chosen for the following programme, limited to 29 measurements.

| Door open | NO | | | | | | | | | | | | YES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cover | NO | | | | | | | | | | YES | YES | NO |
| Mosquito gauze | NO | | | | | | | | | YES | NO | YES | NO |
| Position | I | | | II | | | III | | | II | II | II | II |
| Length | a | b | c | a | b | c | a | b | c | c | c | c | c |
| Diameter 4" | – | – | B1 | – | – | B2 | – | – | B3 | D1 | – | – | – |
| 4"+enl. 6" | – | – | B4 | – | – | B5 | – | – | B6 | D2 | – | – | – |
| 6" | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | D3 | C1 | C2 | C3 |
| 6"+enl. 8" | – | – | B7 | – | – | B8 | – | – | B9 | D4 | – | – | – |
| 8" | – | – | B10 | – | – | B11 | – | – | B12 | D5 | – | – | – |

Table: 3.3 survey test programme

a: 2.40 m b: 2.55m c: 2.80m
–: not covered
A6: code of specific test

## Chapter 4 Recording and evaluation of the results

### 4.1 Recording of the results

Each measurement, A1, A2 etc., will take at least one hour. Two charts are being produced.

Chart 1 : On this chart the ventilation velocity, the velocity of the flow of air going upwards in the vent-pipe is dotted on pressure sensitive paper. This paper is moving with a speed of six inch per hour. The scale is from 0-10 m/s, chart width 5.9 cm.

Chart 2 : This chart gives the results of the anemograph. Total chart width 2.6 inches, chart width per channel 1.0 inch. Chart speed three inches per hour. The left channel indicates the wind velocity, scale from 0-10 m/s. The right channel gives the results of the windvane, wind direction.

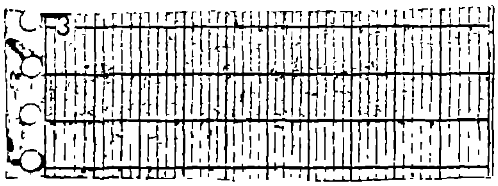


Fig. 4.1 Chart 1, ventilation velocity

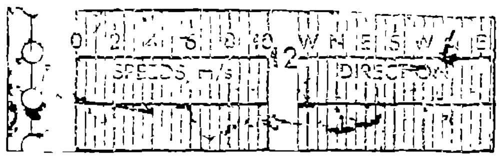


Fig.4.2 Chart 2, anemograph

During the measurements it was noticed, as expected, that there would be a strong correlation between wind velocity and ventilation velocity. Both parameters were displayed on panel meters, wich showed a similar behaviour. To make the correlation visual, I enlarged chart 2 two times.

It is very difficult to read the results from the charts. Therefore all recordings are photocopied and lines are drawn on the photocopies, following the pattern of the points.(Fig.4.3) One line indicates wind velocity, the other line ventilation velocity. In order to find a characteristic relation, approximately thirty corresponding wind/ventilation point are randomly chosen.

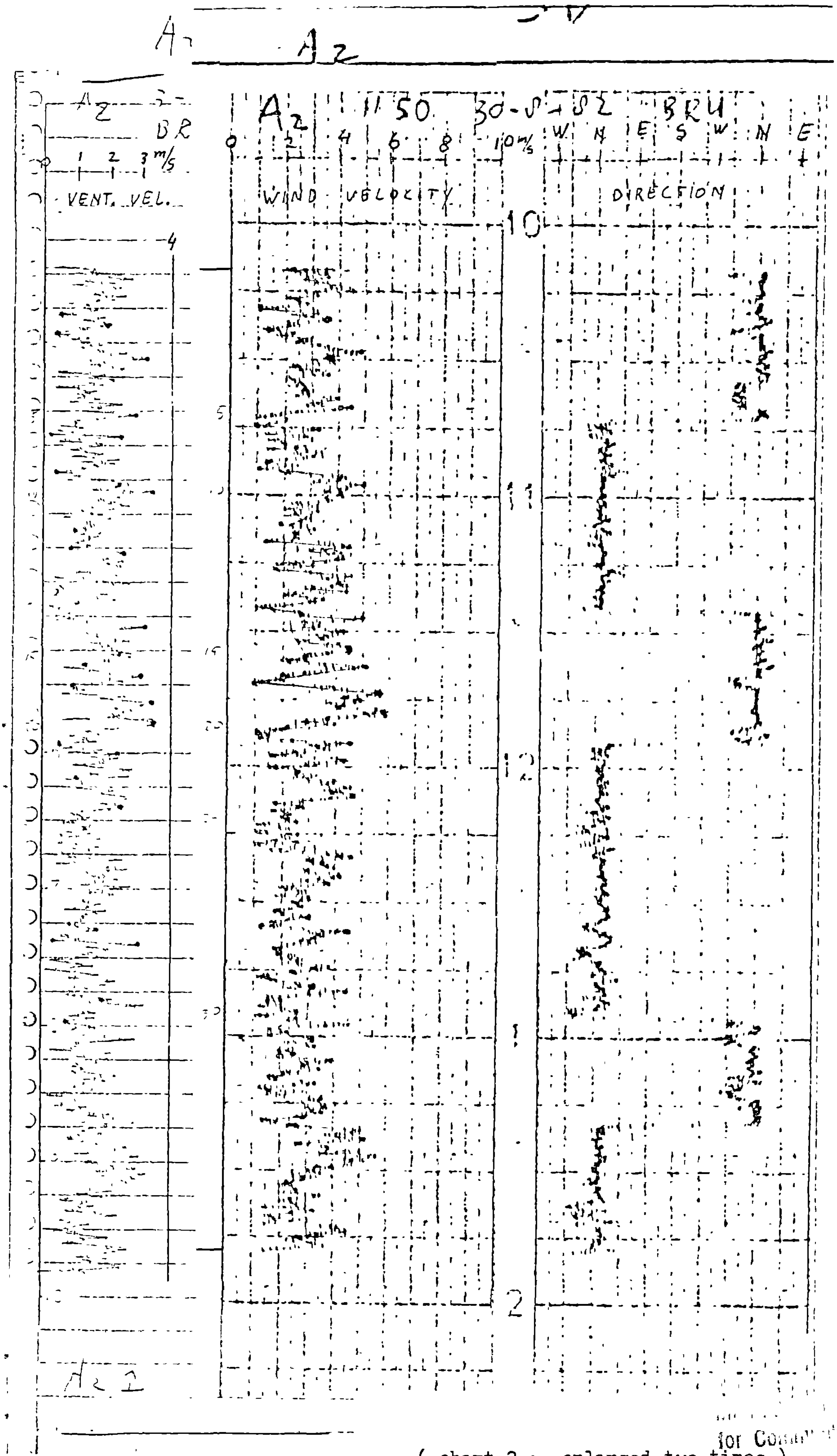



Fig. 4.3 Photocopies of chart 1 and chart 2.

( chart 2 : enlarged two times )

A figure as fig. 4.4 reveals a linear relation between wind- and ventilation velocity.
The relation between wind- and ventilation velocity, expressed in the characteristics: regression coefficient and intercept, has been calculated for all the 29 measurements using the least square method. ( Table 4.1)

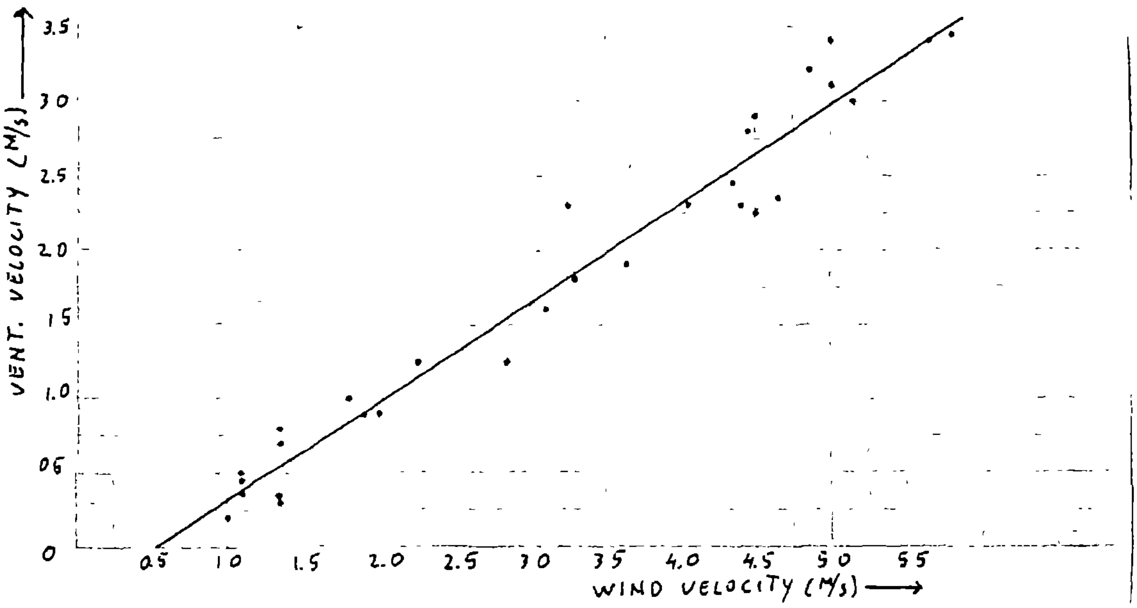



Fig. 4.4 Wind/ventilation velocity relation (measurement A 2)

Table 4.1. Results of the least square method (see also appendix 1)

Y = b x +a b (-) regression coefficient ventilation (m/s)/wind (m/s) velocity

a (m/s) intercept

The following parameters are calculated after the results of the least square method.

Xo (m/s) minimum wind velocity to create ventilation (-a/b)

C ($m^2$) regression coefficient ventilation volume($m^3/s$)/wind velocity (b * area cross-section vent-pipe)

| Code | b | a | Xo | C ($*10^{-3}$) |
|---|---|---|---|---|
| A 1 | 0.7051 | -0.1350 | 0.191 | 10.86 |
| A 2 | 0.6656 | -0.3506 | 0.527 | 10.25 |
| A 3 | 0.6477 | -0.3266 | 0.504 | 9.97 |
| A 4 | 0.5961 | -0.2926 | 0.491 | 9.17 |
| A 5 | 0.5510 | -0.2772 | 0.503 | 6.48 |
| A 6 | 0.5521 | -0.2650 | 0.480 | 8.50 |
| A 7 | 0.5964 | -0.3770 | 0.632 | 9.18 |
| A 8 | 0.5130 | -0.2225 | 0.434 | 7.90 |
| A 9 | 0.5763 | -0.2906 | 0.504 | 8.87 |
| B 1 | 0.5856 | -0.3698 | 0.631 | 5.07 |
| B 2 | 0.5460 | -0.3507 | 0.642 | 4.73 |
| B 3 | 0.6121 | -0.3886 | 0.635 | 5.30 |
| B 4 | 0.7921 | -0.3903 | 0.493 | 6.86 |
| B 5 | 0.7545 | -0.4326 | 0.573 | 6.53 |
| B 6 | 0.6955 | -0.5164 | 0.742 | 6.02 |
| B 7 | 0.7241 | -0.4941 | 0.682 | 11.15 |
| B 8 | 0.7765 | -0.4644 | 0.598 | 11.95 |
| B 9 | 0.7798 | -0.3844 | 0.493 | 12.00 |
| B 10 | 0.4498 | -0.1685 | 0.375 | 16.03 |
| B 11 | 0.4494 | -0.2160 | 0.481 | 16.01 |
| B 12 | 0.4719 | -0.3843 | 0.814 | 16.81 |
| C 1 | 0.3214 | -0.4889 | 1.521 | 4.95 |
| C 2 | 0.2486 | -0.4457 | 1.793 | 4.54 |
| C 3 | 0.4136 | -0.6504 | 1.573 | 6.37 |
| D 1 | 0.4800 | -0.4935 | 1.028 | 4.16 |
| D 2 | 0.6835 | -0.4853 | 0.710 | 5.92 |
| D 3 | 0.4844 | -0,3885 | 0.802 | 7.46 |
| D 4 | 0.6566 | -0.5075 | 0.773 | 10.11 |
| D 5 | 0.4291 | -0.4957 | 1.155 | 15.3 |

Table 4.2 : For all measurements: duration, max.-med.-min. vent.velocity, max.-med.-min. wind velocity, wind stability and wind direction.

| | Length | | Vent. Vel. (m/s) | | | wind vel. (m/s) | | | wind direct. stability | | | prevail |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nr: | min. | sec. | min. | av. | max. | min. | av.* | max. | bad | reas. | good | direct. |
| A1 | 64 | 58 | 0 | 1.2 | 3.05 | 0.3 | 2.1 | 4.0 | | x | | ne |
| A2 | 73 | 37 | 0.2 | 1.7 | 3.45 | 1.0 | 3.1 | 5.8 | | | x | n |
| A3 | 61 | 1 | 0.15 | 1.4 | 3.6 | 0.9 | 2.85 | 6.25 | x | | | n |
| A4 | 71 | 39 | 0 | 1.6 | 3.05 | 0.9 | 3.0 | 5.65 | | | x | n |
| A5 | 65 | 57 | 0.10 | 1.2 | 2.45 | 0.6 | 2.75 | 4.9 | | | x | n |
| A6 | 64 | 34 | 0 | 0.6 | 1.9 | 0.25 | 1.75 | 3.9 | x | | | s s |
| A7 | 87 | 24 | 0 | 1.1 | 3.7 | 0.25 | 2.5 | 6.8 | | x | | se |
| A8 | 63 | | 0 | 0.9 | 2.2 | 0.6 | 2.3 | 4.65 | | x | | se |
| A9 | 64 | 10 | 0.18 | 1.15 | 3.2 | 0.8 | 2.5 | 6.55 | | x | | s-se |
| B1 | 67 | 43 | 0 | 1.25 | 2.7 | 0.30 | 2.75 | 5.70 | | | x | e-se |
| B2 | 59 | 51 | 0 | 1.10 | 2.95 | 0.60 | 2.80 | 6.10 | | x | | e |
| B3 | 72 | 26 | 0 | 1.35 | 3.0 | 0.80 | 3.0 | 5.75 | | x | | e |
| B4 | 69 | 17 | 0.1 | 2.3 | 5.0 | 0.15 | 3.30 | 6.95 | | x | | ne |
| B5 | 66 | 56 | 0 | 1.6 | 4.35 | 0.7 | 2.80 | 6.25 | x | | | ne-e |
| B6 | 59 | 51 | 0 | 1.1 | 3.70 | 0.55 | 2.25 | 5.50 | x | | | e |
| B7 | 64 | 10 | 0 | 0.85 | 3.55 | 0.5 | 1.8 | 4.2 | x | | | e-ne |
| B8 | 65 | 45 | 0 | 2.0 | 5.5 | 0.6 | 3.4 | 6.6 | | x | | n-ne |
| B9 | 82 | 41 | 0 | 1.4 | 4.25 | 0.65 | 2.5 | 5.75 | | x | | ne |
| B10 | 74 | 1 | 0 | 1.2 | 3.25 | 0.8 | 2.95 | 6.5 | | | x | n |
| B11 | 110 | 14 | 0 | 0.75 | 2.35 | 0 | 2.25 | 5.95 | | x | | ne |
| B12 | 80 | 19 | 0 | 0.62 | 2.6 | 0.55 | 2.4 | 6.1 | | x | | +{e-ne<br>n-nw} |
| C1 | 56 | 18 | 0 | 0.3 | 1.35 | 0.6 | 2.4 | 5.9 | | x | | s |
| C2 | 51 | 58 | 0 | 0.2 | 1.0 | 0.55 | 2.5 | 5.7 | | x | | w-sw |
| C3 | 44 | 6 | 0 | 0.6 | 1.65 | 1.1 | 3.25 | 5.9 | | x | | s |
| D1 | 61 | 1 | 0 | 0.95 | 2.7 | 0.75 | 3.15 | 6.6 | | x | | e-ne |
| D2 | 75 | 59 | 0 | 1.55 | 3.8 | 0.6 | 3.0 | 6.35 | | x | | ne |
| D3 | 74 | 1 | 0 | 0.65 | 2.55 | 0.8 | 2.30 | 6.1 | | x | | s-sw |
| D4 | 91 | 44 | 0 | 1.85 | 4.2 | 1.10 | 2.45 | 6.6 | | x | | n-ne |
| D5 | 81 | 53 | 0 | 0.3 | 1.75 | 0.2 | 1.75 | 5.0 | | x | | e |

* The average wind velocity during the 29 measurements is 2.59 m/s

## 4.2 Evaluation of the results

It would be ideal if the ventilation velocity could be described as a function of wind, diameter etc..

Ventilation velocity (m/s) = f (wind, diameter, position, length, mosquito gauze, door, cover)

Hypothetic solution : For position I,II,III, closed door and no cover;

Ventilation $velocity_i$ (m/s) = $\alpha$ wind velocity + $\beta$ diameter + log lenght + $\gamma$ $porosity^2$ mosquito gauze

Due to the limited number of measurements and the lack in knowledge of the theory, it was impossible to find such a solution.

A compleet analysis of variance, to test all parameters on significance, could have been possible if all 240 tests had been made. Unfortunately only 29 tests were executed.

## 4.3 Analysis of variance

### 4.3.1. Ventilation velocity, diameter

Diameter and position can be tested in a two-way classification.
Remarks:
door not open, no cover, no mosquito gauze, length vent-pipe 2.80m.

| Position | I | II | III |
|---|---|---|---|
| Diameter 4" | B1 | B2 | B3 |
| 4" +enl.6" | B4 | B5 | B6 |
| 6" | A3 | A6 | A9 |
| 6" +enl.8" | B7 | B8 | B9 |
| 8" | B10 | B11 | B12 |

(B1: code of measurement, see table 3.3)

Table 4.3: code of measurements diameter / position.

Each cell represents a measurement. For the analysis each measurement, each cell, should be represented by one figure.
The regression coefficient (table 4.1) can not be used as representative figure for each measurement, because most relation lines do not cross the X-coordination line in, or near the same point.
Taking the average value of the ventilation velocity would be very inacurrate, due to the fact that the average value of the wind velocity fluctuate reasonably.
This problem can be avoided by dividing the results of the measurements into two groups: I: wind velocity ⩽ 2.5 m/s
II: wind velocity > 2.5 m/s

A first analysis can be executed by comparing the standard residual deviations. The residual standard deviations are calculated with the least square method.

| Mosq.gauze | NO | | NO | | NO | | YES | |
|---|---|---|---|---|---|---|---|---|
| Position | I | | II | | III | | II | |
| Diameter | ws ⩽ 2.5 | ws > 2.5 | ws ⩽ 2.5 | ws > 2.5 | ws.⩽2.5 | ws >2.5 | ws ⩽ 2.5 | ws > 2.5 |
| 4" | 0.1611 | 0.2532 | 0.1354 | 0.1239 | 0.1678 | 0.3004 | 0.0853 | 0.1040 |
| 4"+enl.6" | 0.3131 | 0.2121 | 0.1753 | 0.3527 | 0.2391 | 0.5238 | 0.1273 | 0.0998 |
| 6" | 0.2085 | 0.3431 | 0.1656 | 0.1423 | 0.0903 | 0.1495 | 0.2363 | 0.1212 |
| 6"+enl.8" | 0.3985 | 0.8238 | 0.1370 | 0.4936 | 0.1800 | 0.4158 | 0.1736 | 0.3043 |
| 8" | 0.1601 | 0.2432 | 0.1828 | 0.1388 | 0.2810 | 0.3991 | 0.09838 | 0.1306 |

Remarks: no cover, door closed, lenght vent-pipe 2.80 m
ws= wind speed (m/s)

Table 4.4 : standard deviations linear regression calculations, ws ⩽ 2.5 m/s and ws > 2.5 m/s.

From table 4.4 can be observed that :

- minimum standard deviation 0.0903,
- maximum standard deviation 0.8283.

The spreading in the standard deviation is too big, to use the average value of the ventilation velocity for an analysis of variance. A variance stabilizing transformation is therefore necessary.

- standard deviation > 0.30 can often be found when:

a: an enlarger is used

b: windspeed > 2.5 m/s.

The standard deviations are remarkably low when mosquito gauze is used.

Mosquito gauze has a stabilizing influence on the results of the measurements.

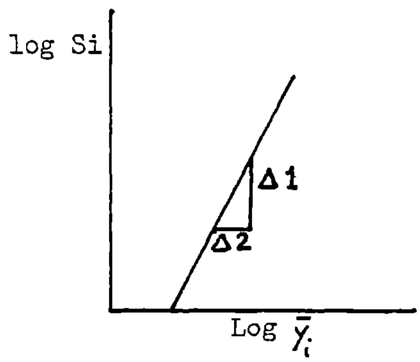
Variance Stabilizing Transformation

Explanation of the variance stabilizing transformation theory can be found in Ref. 20 (p. 232/238).

Procedure : If $\bar{y}_i$ = the average value of the ventilation velocity (m/s) in each cell, than $\bar{z} = \bar{y}^{\lambda}$ is the transformed average value of the ventilation velocity.

$\lambda = 1 - \alpha$

$\alpha$ can empirically be found. (Fig. 4.5,table 4.5)




Si = standard deviation

$\alpha = \frac{\Delta 1}{\Delta 2}$

Fig. 4.5 Calculation of variance stabilizing coefficient

Table 4.5 Variance stabilizing transformation

$\bar{Y}i$ : average value of ventilation velocity (M/s)

Si : standard deviation

$\bar{Z}i$ : $\bar{Y}_i^{\lambda}$

ws : wind speed  I ≤ 2.5 (m/s) , II > 2.5 (m/s)

| Code | ws | $\bar{Y}i$ | Si | log $\bar{Y}i$ | log Si | $\bar{Z}i$ |
|---|---|---|---|---|---|---|
| B1 | I | 0.638 | 0.1611 | -0.195 | -0.793 | 0.849 |
| B1 | II | 1.633 | 0.2532 | 0.213 | -0.597 | 1.461 |
| B2 | I | 0.562 | 0.1354 | -0.25 | -0.868 | 0.640 |
| B2 | II | 2.106 | 0.1239 | 0.323 | -0.907 | 1.779 |
| B3 | I | 0.471 | 0.1678 | -0.327 | -0.775 | 0.559 |
| B3 | II | 2.439 | 0.3004 | 0.387 | -1.522 | 1.993 |
| B4 | I | 1.007 | 0.3131 | 0.003 | -0.504 | 1.005 |
| B4 | II | 2.902 | 0.2121 | 0.463 | -0.673 | 2.228 |
| B5 | I | 0.718 | 0.1753 | -0,144 | -0.756 | 0.774 |
| B5 | II | 2.821 | 0.3527 | 0.450 | -0.453 | 2.230 |
| B6 | I | 0.52 | 0.2391 | -0.284 | -0.621 | 0.603 |
| B6 | II | 2.150 | 0.5238 | 0.332 | -0.281 | 1.808 |
| A3 | I | 0.859 | 0.2085 | -0.066 | -0.681 | 0.889 |
| A3 | II | 2.056 | 0.3431 | 0.313 | -0.465 | 1.746 |
| A6 | I | 0.485 | 0.1656 | -0.314 | -0.781 | 0.571 |
| A6 | II | 1.425 | 0.1423 | 0.154 | -0.847 | 1.315 |
| A9 | I | 0.411 | 0.0903 | -0.386 | -1.044 | 0.503 |
| A9 | II | 2.053 | 0.1495 | 0.312 | -0.825 | 1.744 |
| B7 | I | 0.728 | 0.3985 | -0.138 | -0.400 | 0.782 |
| B7 | II | 1.586 | 0.8238 | 0.200 | -0.084 | 1.429 |
| B8 | I | 0.796 | 0.1370 | -0.099 | -0.863 | 0.838 |
| B8 | II | 3.058 | 0.4936 | 0.485 | -0.307 | 2.374 |
| B 9 | I | 0.609 | 0.1800 | -0.215 | -0.745 | 0.681 |
| B 9 | II | 2.836 | 0.4158 | 0.453 | -0.381 | 2.240 |
| B10 | I | 0.638 | 0.1601 | -0.195 | -0.796 | 0.706 |
| B10 | II | 1.708 | 0.2432 | 0.232 | -0.614 | 1.513 |
| B11 | I | 0.475 | 0.1828 | -0.323 | -0.738 | 0.562 |
| B11 | II | 1.595 | 0.1388 | 0.203 | -0.858 | 1.435 |
| B12 | I | 0.486 | 0.2810 | -0.313 | -0.551 | 0.572 |
| B12 | II | 1.373 | 0.3991 | 0.138 | -0.399 | 1.278 |

$\alpha = 0.2265$  $\lambda = 0.7735$

| Diameter | POSITION I | | POSITION II | | POSITION III (k = 6) | | |
|---|---|---|---|---|---|---|---|
| | ws < 2.5 m/s | ws > 2.5 m/s | ws < 2.5 m/s | ws > 2.5 m/s | ws < 2.5 m/s | ws > 2.5 m/s | |
| 4" | 0.849 | 1.461 | 0.640 | 1.779 | 0.559 | 1.993 | 1.214 |
| 4" +enl.6" | 1.005 | 2.228 | 0.774 | 2.230 | 0.603 | 1.808 | 1.441 |
| 6" | 0.889 | 1.746 | 0.571 | 1.315 | 0.503 | 1.744 | 1.128 |
| 6" +enl.8" | 0.782 | 1.429 | 0.838 | 2.734 | 0.681 | 2.24 | 1.451 |
| n = 5<br>8" | 0.706 | 1.513 | 0.562 | 1.435 | 0.572 | 1.278 | 1.011 |
| | 0.846 | 1.675 | 0.677 | 1.899 | 0.584 | 1.813 | $\bar{Z}$=1.249 |

Table 4.6 Values of transformed average ventilation velocities $\bar{Z}_i$; Remarks : no cover
no mosquito gauze
door closed
length vent-pipe 2.80 m

Table 4.7 Analysis of variance table, transformed values of average wind velocity.

| source of variation | sum of squares | degrees of freedom | mean square | ratio of mean squares |
|---|---|---|---|---|
| diameter | $S_b = 0.901$ | n-1 =4 | $S_b^2 = 0.225$ | $S_b^2/S_d^2 = 3.516$ |
| position/ws | $S_c = 9.27$ | k-1 =5 | $S_c^2 = 1.854$ | $S_c^2/S_d^2 = 29$ |
| residuals | $S_d = 1.272$ | (n-1)(k-1)=20 | $S_d^2 = 0.064$ | |
| Total | S =11.44 | N-1 = 29 | | |

With information of table 4.7, the following can be revealed.

The F-test indicates that the influence of position/wind speed is absolutely significant. This could be expected as a result of the division of wind speed into two groups.
The most important conclusion, however, is that the influence of the diameter on ventilation velocity is not significant ( $F_{0.05}$ (5/20)=4.76)) within the limits of acuracy of this research.

## 4.3.2 ventilation volume ($m^3/s$), diameter

Ventilation volume calculated as :

ventilation velocity*Area of cross-section vent-pipe.
(Flow characteristics, turbulent)

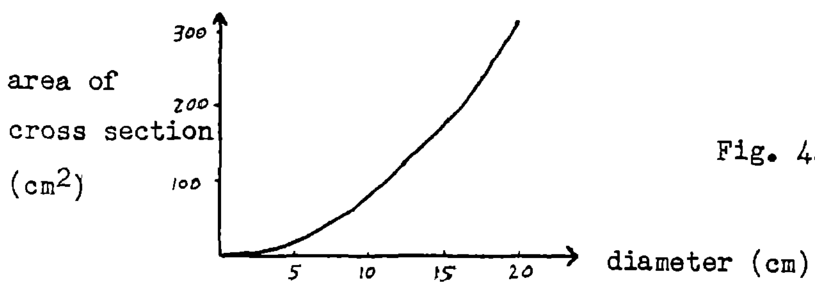



Fig. 4.6: diameter/area of cross-section

An analysis of variance is applied on ventilation volume, position/ wind speed.

Table 4.8 Variance stabilizing transformation, ventilation volume.

| Code | ws | $\bar{Y}i' = (\bar{Y}_i * A)$ | $Si' = (Si * A)$ | $\mathrm{Log}(\bar{Y}i' \cdot 10^3)$ | $\mathrm{Log}(Si' \cdot 10^3)$ | $\bar{Z}i'$ |
|---|---|---|---|---|---|---|
| B1 | I | $5.52 \cdot 10^{-3}$ | $1.39 \cdot 10^{-3}$ | 0.74 | 0.14 | 1.98 |
| B1 | II | 14.14 | 2.19 | 1.15 | 0.34 | 2.89 |
| B2 | I | 4.87 | 1.17 | 0.69 | 0.07 | 1.88 |
| B2 | II | 18.24 | 1.07 | 1.26 | 0.03 | 3.19 |
| B3 | I | 4.08 | 1.45 | 0.61 | 0.16 | 1.75 |
| B3 | II | 21.12 | 2.60 | 1.32 | 0.41 | 3.39 |
| B4 | I | 8.72 | 2.71 | 0.94 | 0.43 | 2.38 |
| B4 | II | 25.13 | 1.84 | 1.40 | 0.26 | 3.63 |
| B5 | I | 6.22 | 1.52 | 0.79 | 0.18 | 2.08 |
| B5 | II | 24.43 | 3.05 | 1.39 | 0.48 | 3.59 |
| B6 | I | 4.50 | 2.07 | 0.65 | 0.32 | 1.83 |
| B6 | II | 18.62 | 4.54 | 1.27 | 0.66 | 3.22 |
| A3 | I | 13.22 | 3.21 | 1.12 | 0.51 | 2.81 |
| A3 | II | 31.65 | 5.28 | 1.50 | 0.72 | 3.98 |
| A6 | I | 7.47 | 2.55 | 0.87 | 0.41 | 2.24 |
| A6 | II | 21.94 | 2.19 | 1.34 | 0.34 | 3.44 |
| A9 | I | 6.33 | 1.39 | 0.80 | 0.14 | 2.09 |
| A9 | II | 31.6 | 2.30 | 1.50 | 0.36 | 3.98 |
| B7 | I | 11.21 | 6.13 | 1.05 | 0.79 | 2.63 |
| B7 | II | 24.41 | 5.05 | 1.39 | 0.70 | 3.59 |
| B8 | I | 12.25 | 2.11 | 1.09 | 0.32 | 2.72 |
| B8 | II | 47.07 | 7.60 | 1.67 | 0.88 | 4.67 |
| B9 | I | 9.37 | 2.77 | 0.97 | 0.44 | 2.45 |
| B9 | II | 43.65 | 6.40 | 1.64 | 0.81 | 4.53 |
| B10 | I | 22.73 | 5.72 | 1.36 | 0.76 | 3.49 |
| B10 | II | 60.86 | 8.67 | 1.78 | 0.94 | 5.17 |
| B11 | I | 16.93 | 6.51 | 1.23 | 0.81 | 3.10 |
| B11 | II | 56.83 | 4.95 | 1.75 | 0.69 | 5.03 |
| B12 | I | 17.32 | 10.01 | 1.24 | 1.00 | 3.13 |
| B12 | II | 48.92 | 14.22 | 1.69 | 1.15 | 4.74 |

Remarks : $\bar{Y}i' = \bar{y}_i * A$ : ventil. volume ($10^{-3}$ $m^3/s$)
$Si' =$ standard deviation
$Zi' = \bar{Y}i'^{\lambda}$ stabilized value of $\bar{Y}i'$
$\lambda = 1 - \alpha$ $\alpha = 0.60$

B1 / B6 $A = 3.66 \quad 10^{-3} m^2$
A3 / A9 and B7 / B9 $A = 15.39 \quad 10^{-3} m^2$
B10/B12 $A = 35.63 \quad 10^{-3} m^2$

| DIAMETER | POSITION I | | POSITION II | | POSITION III K=6 | | |
|---|---|---|---|---|---|---|---|
| | ws 2.5 m/s | ws 2.5 m/s | ws 2.5 m/s | ws 2.5 m/s | ws 2.5 m/s | ws 2.5 m/s | |
| 4" | 1.98 | 2.89 | 1.88 | 3.19 | 1.75 | 3.39 | 2.51 |
| 4" +enl.6" | 2.38 | 3.63 | 2.08 | 3.59 | 1.83 | 3.22 | 2.79 |
| 6" | 2.81 | 3.98 | 2.24 | 3.44 | 2.09 | 3.98 | 3.09 |
| 6" +enl.8" | 2.63 | 3.59 | 2.72 | 4.67 | 2.45 | 4.53 | 3.43 |
| n = 5<br>8" | 3.49 | 5.17 | 3.10 | 5.03 | 3.13 | 4.74 | 4.11 |
| | 2.66 | 3.85 | 2.40 | 3.98 | 2.25 | 3.97 | $\bar{Z}_{i} = 3.19$ |

Table 4.9 Analysis of variance transformed values of ventilation volume. $\bar{Z}_i$

Remarks : No mosquito gauze
No cover
Pipe length 2.80 (m)

Table 4.10 Analysis of variance table, transformed average values of ventilation volume.

| source of variation | sum of squares | degrees of freedom | mean square | ratio of mean squares |
|---|---|---|---|---|
| diameter | $S_b = 9.22$ | $n-1 = 4$ | $s_b^2 = 2.31$ | $s_b^2/s_d^2 = 29.6$ |
| position/ws | $S_c = 17.28$ | $k-1 = 5$ | $s_c^2 = 3.46$ | $s_c^2/s_d^2 = 44.4$ |
| residuals | $S_d = 1.56$ | $(n-1)(k-1) = 20$ | $s_d^2 = 0.078$ | |
| total | $S = 28.06$ | $N-1 = 29$ | | |

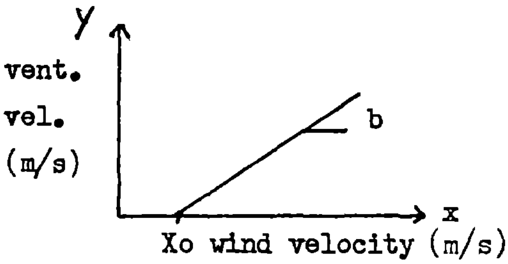
$F_{0.005}(4/20) = 5.17$ $F_{0.005}(5/20) = 4.76$

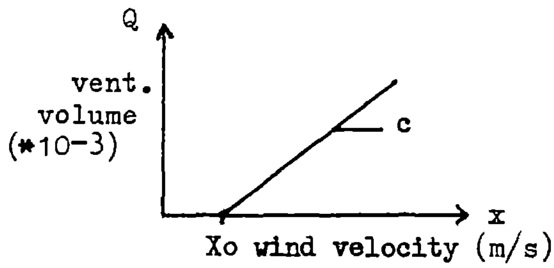
Table 4.10 shows obviously that the influence of diameter on ventilation volume is significant. The ratio of mean squares ($F_{0.005}(4/20)=5.17$) $s_b^2/s_d^2 = 29.6$ exceeds enormously the 0.5% significance level.

The high ratio of mean squares for position/ws can be explaned by the division of the wind velocity into two groups.

### 4.3.3 Quantification of influence of diameter on ventilation volume.

In table 4.11 the ventilation velocity / wind velocity relation is transformed by multiplying with the area of cross-section concerned, to a ventilation volume/ wind velocity relation.




| Diameter | Code | Xo | b | $C \cdot 10^{-3}$ | Q ($m^3/s$) for a wind speed of 2.59 m/s ($* 10^{-3}$) |
|---|---|---|---|---|---|
| 4" | B1 | 0.631 | 0.5856 | 5.071 | 9.93 |
| 4" | B2 | 0.642 | 0.5460 | 4.728 | 9.21 |
| 4" | B3 | 0.635 | 0.6121 | 5.300 | 10.36 |
| 4"+6"enl. | B4 | 0.493 | 0.7921 | 6.859 | 14.38 |
| 4"+6"enl. | B5 | 0.573 | 0.7545 | 6.533 | 13.18 |
| 4"+6"enl. | B6 | 0.742 | 0.6955 | 6.023 | 11.13 |
| 6" | A3 | 0.504 | 0.6477 | 9.971 | 20.8 |
| 6" | A6 | 0.480 | 0.5521 | 8.499 | 17.93 |
| 6" | A9 | 0.504 | 0.5763 | 8.872 | 18.51 |
| 6"+8"enl. | B7 | 0.682 | 0.7241 | 11.147 | 21.27 |
| 6"+8"enl. | B8 | 0.598 | 0.7765 | 11.953 | 23.81 |
| 6"+8"enl. | B9 | 0.493 | 0.7798 | 12.004 | 25.17 |
| 8" | B10 | 0.375 | 0.4498 | 16.027 | 35.50 |
| 8" | B11 | 0.481 | 0.4424 | 16.013 | 33.77 |
| 8" | B12 | 0.481 | 0.4719 | 16.815 | 35.46 |

Table 4.11 Results diameter.

Comparing the different values of c, ignoring the different values of x, we see that;

Diameter / enlarger

Both, diameter and enlarger, are significant parameters.

a 6" enlarger put on a 4" pipe will increase efficiency with ±29%
a 8" enlarger put on a 6" pipe will increase efficiency with ±28%

The respective figures in percentages of regression coefficient C for the vent. pipes with/without enlargers are:

| | |
|---|---|
| 4" | 55% |
| 4" + 6" enl. | 71 |
| 6" | 100 |
| 6" + 8" enl. | 128 |
| 8" | 178 |

Roughly can be stated, that these figures can be applied also on ventilation volumes ($m^3/s$).

## 4.4 Mosquito gauze

The influence of mosquito gauze on ventilation has been tested on the five different diameters.

The mosquito gauze used, is from Fothersgill & Harvey Ltd. U.K.;

No. of threads/cm: 7.0 in one direction and
5.5 in the other
Thread diameter : 0.25 mm
per square cm, 0.288 $cm^2$ is covered by mosquito gauze.

The reduction in ventilation volume, due to the influence of mosquito gauze is significant. (Table 4.11).
The average values of the ventilation velocities are transformed as in table 4.5. The results are compared to the transformed values of the ventilation volumes, of the identical tests without mosquito gauze, minus two times the standard deviation. (0.078).

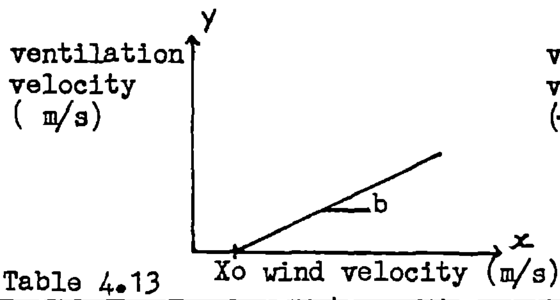
| Code | Diam. | ws | $\bar{Y}$(m/s) | s.d. | $\bar{Y}'$ $10^{-3}$ ($m^3$/s) | $\bar{Z}'=\bar{Y}'^{0.4}$ | Code | Zi' - ,166 (table 4.8) |
|---|---|---|---|---|---|---|---|---|
| D1 | 4" | I | 0.296 | 0.0853 | 2.56 | 1.46 | B2 | 1.72 |
| | | II | 1.503 | 0.104 | 13.06 | 2.79 | | 3.03 |
| D2 | 4"+6"enl. | I | 0.427 | 0.1273 | 3.70 | 1.69 | B5 | 1.92 |
| | | II | 2.784 | 0.0998 | 24.11 | 3.57 | | 4.43 |
| D3 | 6" | I | 0.338 | 0.2363 | 5.20 | 1.93 | A6 | 2.08 |
| | | II | 1.650 | 0.1212 | 25.4 | 3.65 | | 3.28 |
| D4 | 6"+8"enl. | I | 0.773 | 0.1736 | 11.90 | 2.69 | B8 | 2.56 |
| | | II | 2.553 | 0.3043 | 39.30 | 4.37 | | 4.51 |
| D5 | 8" | I | 0.321 | 0.0984 | 11.44 | 2.65 | B11 | 2.94 |
| | | II | 0.900 | 0.1306 | 32.07 | 4.00 | | 4.87 |

Table 4.12 Mosquito gauze significance testing

In eight out of ten times, $Z' < (Z_i^* - 0.166)$

However, it is difficult to say exactly, in figures, how much reduction in ventilation volume is caused by the use of mosquito gauze.

An attempt is made in table 4.13.



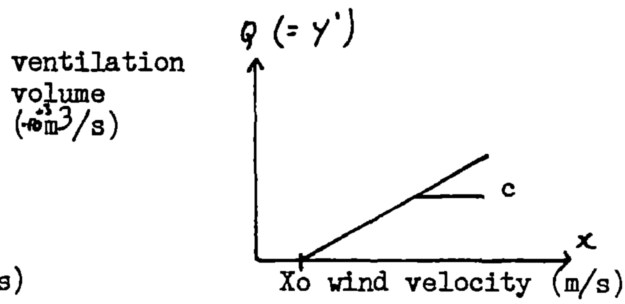




Table 4.13

| Code | Diameter | Xo | ΔXo | b | S(b) | c($10^{-3}$) | Q* ($10^{-3}$ $m^3$/s) | |
|---|---|---|---|---|---|---|---|---|
| B2 | 4" | 0.642 | | 0.5460 | 0.015 | 4.728 | 9.21 | |
| D1 | | 1.028 | 0.39 | 0.4800 | 0.012 | 4.156 | 6.49 | -30% |
| B5 | 4"+6"enl | 0.573 | | 0.7545 | 0.035 | 6.533 | 13.18 | |
| D2 | | 0.710 | 0.14 | 0.6835 | 0.011 | 5.918 | 11.13 | -16% |
| A6 | 6" | 0.480 | | 0.5521 | 0.027 | 8.499 | 17.93 | |
| D3 | | 0.802 | 0.32 | 0.4844 | 0.012 | 7.457 | 13.33 | -26% |
| B8 | 6"+8"enl | 0.598 | | 0.7765 | 0.023 | 11.953 | 23.81 | |
| D4 | | 0.773 | 0.18 | 0.6566 | 0.026 | 10.108 | 18.37 | -23% |
| B11 | 8" | 0.481 | | 0.4494 | 0.021 | 16.013 | 33.77 | |
| D5 | | 1.155 | 0.67 | 0.4291 | 0.023 | 15.290 | 21.94 | -35% |

* ws = 2.59(m/s)

Remarks : Xo minimum wind velocity required to create ventilation
b regression coefficient vent.velocity/wind velocity
S(b) standard deviation regression coefficient.
c regression coefficient vent.volume/wind velocity
Q ventilation volume ($m^3/s$), wind velocity is 2.59 m/s. 2.59 m/s is the average wind velocity during the 29 measurements.

The minimum wind velocity to create ventilation is increased by the application of mosquito gauze on the top of a vent-pipe. The average increase is 0.34 m/s.
The average redusction in ventilation volume for a wind velocity of 2.59 m/s is 26%.
Both Xo and the reduction in ventilation volume vary reasonably. Therefore, the figures of 0.34 m/s and 26% should be seen as indications.

## 4.5 Cover

The results of the two tests, C1 and C2, reveal a significant influence on ventilation efficiency, due to the use of a cover on :

- Xo minimum wind speed required to create ventilation
- b regression coefficient ventilation/wind velocity
- c regression coefficient ventilation volume/wind velocity.

| Code | characteristics | Xo | b | S(b) | $C \times 10^{-3}$ | Vent.velocity (m/s) for ws 2.59 m/s. | |
|---|---|---|---|---|---|---|---|
| A6 | reference | 0.480 | 0.5521 | 0.027 | 8.50 | 1.165 | 100% |
| D3 | mosquito gauze | 1.028 | 0.4844 | 0.013 | 7.46 | 0.866 | 74% |
| C1 | cover on key hole | 1.521 | 0.3210 | 0.017 | 4.95 | 0.344 | 30% |
| C2 | cover on key hole + mosquito gauze | 1.793 | 0.2486 | 0.027 | 4.54 | 0.198 | 17% |

Table 4.14 Results Cover

Remarks: 6" vent-pipe, position II, length 2.80 m.

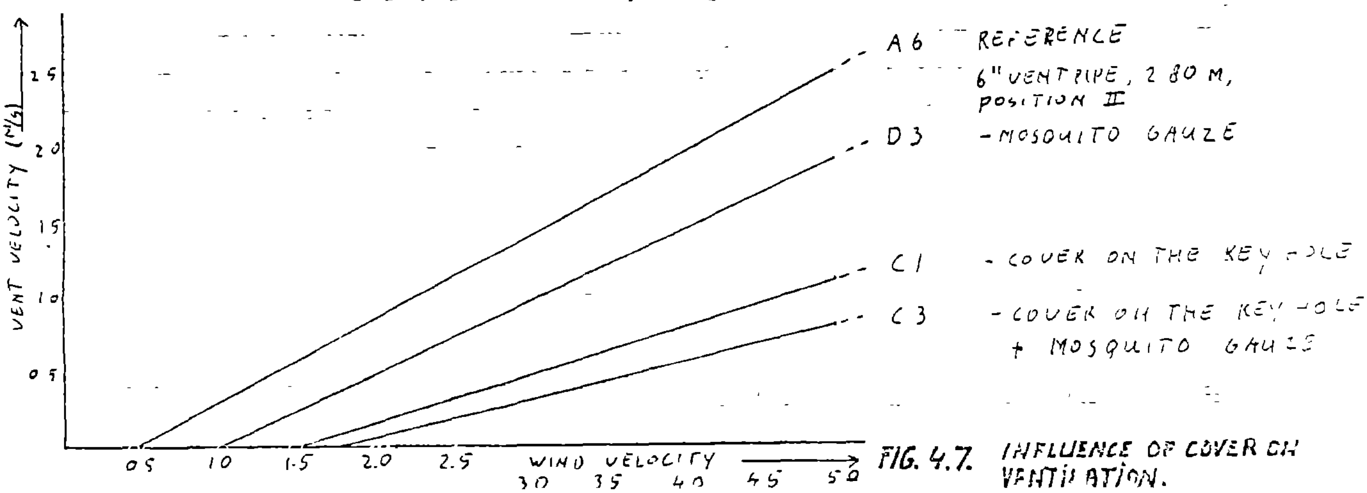
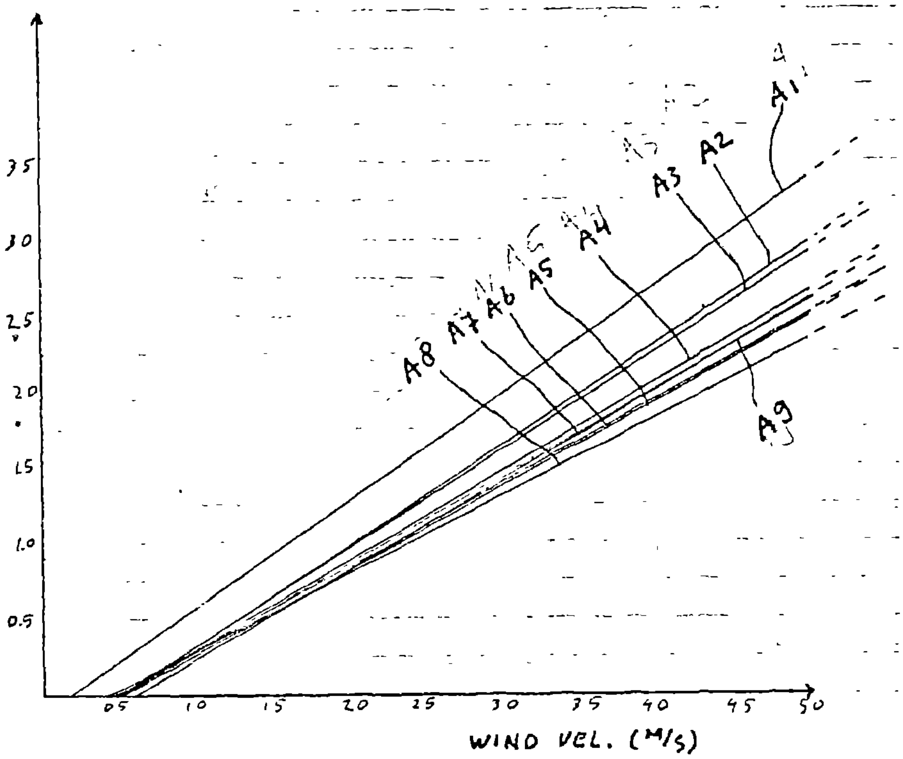



FIG. 4.7. INFLUENCE OF COVER ON VENTILATION.

The use of a cover reduces ventilation efficiency to 30%, in relation to an open vent-pipe.
The combination of mosquito gauze + cover has a disastrous impact on ventilation. The minimum wind speed required to create ventilation is 1.79 m/s, while the regression coefficient b dropps to 0.25.

## 4.6 Position /Length vent-pipe

The results of the measurements expressed in intercept and regression coefficient (table 4.1, fig.4.8) reveal as favourable combination : the shortest pipe of 2.40 m on position I.




| LENGTH | POSITION | | |
|---|---|---|---|
| | I | II | III |
| 2.40 | A1 | A4 | A7 |
| 2.55 | A2 | A5 | A8 |
| 2.80 | A3 | A6 | A9 |

Remark: 6" vent-pipe

FIG. 4.8 influence of position/ length vent-pipe

Although this positive effect is explanable (Chapter 3.4), the reliability of measurement A1 is low.
A 95% reliability interval around the wind/ventilation velocity relation includes all the other measurements.

The conclusion must be that position or length does not influence ventilation efficiency significantly.

## 4.7 Open/closed door

The effect of cross-ventilation is more experienced with an open door.

The only measurement executed with an open door shows the following results.

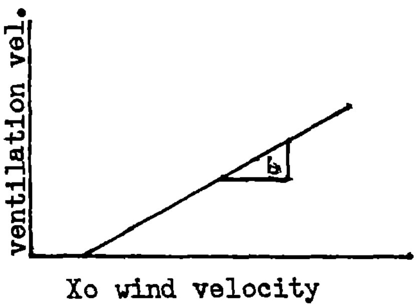
- The minimum wind velocity Xo required is ± 1.6 m/s
- The regression coefficient c, representing the linear relation between ventilation volume and wind velocity, dropps to 0.4136.

## Chapter 5 Conclusions and design guidelines

- Mechanism of ventilation

This study finds a linear relation between wind velocity and ventilation velocity.

Wind blowing over a vent-pipe creates an under-pressure. Due to the difference in pressure pit/top vent-pipe, ventilation will take place.




Xo Minimum wind speed required to create ventilation

$b = \frac{\Delta \text{ ventilation velocity}}{\Delta \text{ wind velocity}}$

Fig. 5.1 Wind/ventilation velocity relation.

A minimum wind velocity (Xo) is required to create ventilation. When the wind velocity exceeds Xo, a linear relation between wind/ventilation is established.

The most important conclusion is that a VIP latrine needs wind to create ventilation. Xo and the coefficient a depend on a number of parameters, such as diameter vent-pipe, design of superstructure etc.

- Standard

The required ventilation volume is not defined, see chapter 2.3.

To my opinion, an air change of the superstructure every five minutes will quarentee that odour inside the superstructure after use will be sufficiently removed. A contineous air flow ensures that odours from the pit won't enter the superstructure. The volume of the VIP superstructure is 2.1 $m^3$.

A volume flow of 25 $m^3/h$ ($6.94 \cdot 10^{-3}$ $m^3/s$ ) satisfies, not considering the positive effect of cross-ventilation.

- Diameter of vent-pipe, the use of enlargers.

The following types were selected :

4" diameter
4" diameter + 6" enlarger
6" diameter
6" diameter + 8" enlarger
8" diameter

The influence of diameter/enlarger could not be statistically prooved. Ventilation volume ($m^3/s$) , induced by wind, is significantly depending on diameter/enlarger.
Roughly can be stated :

| 'Diameter' | 4" | 4"+6"enl. | 6" | 6"+8"enl. | 8" |
|---|---|---|---|---|---|
| Vent. efficiency | 55% | 71% | 100% | 128% | 178% |

More interesting is the question of wich diamter should be used. The answer depends on the wind situation. In a windy area a 4" or a 4"+6" enl. will meet the needs.
On a location where not much wind is experienced, a 6"; 6"+ 8"enl. or even a 8" diameter vent-pipe should be fixed. However, when the average wind velocity is less than 1 m/s, the ventilation as described in this report does not function properly.

- Mosquito gauze

The mosquito gauze used, is from Fothersgill & Harvey Ltd. U.K.

Numbers of threads/cm: 7.0 in one direction
5.5 in the other
Thread diameter : 0.25 mm

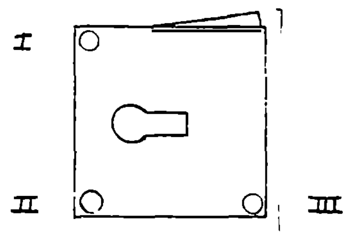
The use of mosquito gauze reduces ventilation efficiency.

- Xo the minimum wind speed required to create ventilation is increased (roughly ± 0.35 m/s)
- c the regression coefficient ventilation volume/wind velocity is decreased.

The reduction in ventilation volume for a wind speed of 2.59 m/s, the over-all average ventilation velocity during the measurements, is approximately 25%.
Mosquito gauze is essential for proper functioning of a VIP latrine. The reduction in ventilation efficiency should therefore be kept in mind before choosing the type of vent-pipe.

- Cover
The function of a cover is to prevent flies and mosquitos from entering and leaving the pit.
With regard to ventilation, a cover is a severe obstacle to flow. The combination of mosquito gauze + cover is fatal for ventilation. The minimum wind velocity, before ventilation starts working, is appr. 1.8 m/s. A cover should therefore not be used. However, when the superstructure is not able to ensure relative darkness, hence flies prefer to leave the pit through the squatting slab instead of through the vent-pipe, then a cover has to be used.

- Position/length vent-pipe
The Dar es Salaam type of VIP latrine has installed the vent-pipe inside the superstructure of the latrine. Three positions and three different pipe lengths were selected.




No influence of these parameters on ventilation could statistically be prooved. However, the top of the vent-pipe should reach at least the highest point of the roof. Using the minimum length as mentioned here above, than the most preferable position is where the top of the vent-pipe is located near the top of the roof. This will avoid a positive wind gradient and hence wind blowing into the top of the vent-pipe reducing ventilation efficiency. The positive gradient might be induced by the slope of the roof. The length of the vent-pipe might even be increased when f.i. the latrine is located in between two houses.

APPENDIX 1

Results of least square method and statistical information for each measurement seperately.

Each page gives for one measurement the following information :

| | |
|---|---|
| - b | regression coefficient |
| - a | intercept |
| - R | correlation coefficient |
| - S(y,x) | residual standard deviation |
| - S(a) | standard deviation intercept |
| - S(b) | standard deviation regression coefficient b |
| - t | test for intercept a; (N-2) degrees of freedom |
| - t | test for regression coefficient b; (N-2) degrees of freedom |
| - SS(y) | total summ of squares; (N-1) degrees of freedom |
| - SS(reg) | summ of squares ascribed to regression-equation |
| - SS(res) | summ of squares ascribed to deviations of regression-equation; (N-2) degrees of freedom |
| - n | number of points concerned |

Table 3.3 Survey test programme, explanes codes used.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Door open | NO | | | | | | | | | | | | YES |
| Cover | NO | | | | | | | | | | YES | YES | NO |
| Mosquito gauze | NO | | | | | | | | | YES | NO | YES | NO |
| Position | I | | | II | | | III | | | II | II | II | II |
| Length | a | b | c | a | b | c | a | b | c | c | c | c | c |
| Diameter 4" | - | - | B1 | - | - | B2 | - | - | B3 | D1 | - | - | - |
| 4"+enl. 6" | - | - | B4 | - | - | B5 | - | - | B6 | D2 | - | - | - |
| 6" | A1 | A2 | A3 | A4 | A5 | A6 | A7 | A8 | A9 | D3 | C1 | C2 | C3 |
| 6"+enl. 8" | - | - | B7 | - | - | B8 | - | - | B9 | D4 | - | - | - |
| 8" | - | - | B10 | - | - | B11 | - | - | B12 | D5 | - | - | - |

Table: 3.3 survey test programme

a: 2.40 m b: 2.55m c: 2.80m

-: not covered

A6: code of specific test

Y=bX+a
b= 0.7051E+00
a=-0.1350E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.8837E+00 |
| de residuele standaardafwijking | S(y,x)= 0.4080E+00 |
| de standaardfout in het intercept | S(a)= 0.1475E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.6934E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.9156E+00 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.1017E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.2205E+02 |
| de kwadraatsom, toe te schrijven aan de regressievergelijking | SS(reg)= 0.1722E+02 |
| de kwadraatsom, toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.4829E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 0.900 | 0.550 |
| 2 | 2.950 | 1.800 |
| 3 | 0.850 | 0.400 |
| 4 | 1.350 | 0.900 |
| 5 | 3.450 | 2.450 |
| 6 | 0.950 | 0.350 |
| 7 | 1.700 | 1.150 |
| 8 | 3.050 | 2.500 |
| 9 | 0.002 | 1.700 |
| 10 | 0.700 | 0.100 |
| 11 | 2.200 | 1.250 |
| 12 | 0.850 | 0.000 |
| 13 | 0.950 | 0.100 |
| 14 | 3.650 | 2.400 |
| 15 | 0.650 | 0.000 |
| 16 | 1.750 | 0.950 |
| 17 | 0.650 | 0.250 |
| 18 | 1.750 | 1.200 |
| 19 | 1.600 | 1.100 |
| 20 | 2.450 | 1.400 |
| 21 | 2.850 | 1.700 |
| 22 | 0.600 | 0.100 |
| 23 | 2.550 | 1.700 |
| 24 | 0.750 | 0.250 |
| 25 | 2.350 | 1.250 |
| 26 | 2.550 | 1.600 |
| 27 | 0.900 | 0.250 |
| 28 | 2.350 | 1.800 |
| 29 | 2.900 | 1.950 |
| 30 | 4.000 | 3.050 |
| 31 | 3.000 | 1.950 |

Y=bX+a
b= 0.6656E+00
a=-0.3506E+00

| | | |
|---|---|---|
| de correlatiecoefficient | R= | 0.9789E+00 |
| de residuele standaardafwijking | S(y,x)= | 0.2268E+00 |
| de standaardfout in het intercept | S(a)= | 0.9381E-01 |
| de standaardfout in reg.coefficient b: | S(b)= | 0.2628E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= | 0.3737E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= | 0.2533E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= | 0.3446E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= | 0.3302E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= | 0.1441E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.100 | 0.500 |
| 2 | 3.650 | 1.900 |
| 3 | 1.350 | 0.350 |
| 4 | 4.850 | 3.200 |
| 5 | 4.450 | 2.800 |
| 6 | 1.000 | 0.200 |
| 7 | 3.250 | 2.300 |
| 8 | 1.100 | 0.350 |
| 9 | 4.050 | 2.300 |
| 10 | 5.000 | 3.400 |
| 11 | 1.850 | 0.900 |
| 12 | 1.350 | 0.800 |
| 13 | 4.350 | 2.450 |
| 14 | 5.000 | 3.100 |
| 15 | 4.400 | 2.300 |
| 16 | 2.850 | 1.250 |
| 17 | 5.150 | 3.000 |
| 18 | 2.000 | 0.900 |
| 19 | 5.650 | 3.400 |
| 20 | 5.800 | 3.450 |
| 21 | 1.100 | 0.450 |
| 22 | 4.500 | 2.250 |
| 23 | 1.800 | 1.000 |
| 24 | 4.650 | 2.350 |
| 25 | 2.250 | 1.250 |
| 26 | 3.100 | 1.600 |
| 27 | 1.350 | 0.300 |
| 28 | 4.500 | 2.900 |
| 29 | 3.300 | 1.800 |
| 30 | 1.350 | 0.700 |

```
Y=bX+a
b= 0.6477E+00
a=-0.3266E+00
de correlatiecoefficient                              R= 0.9387E+00
de residuele standaardafwijking                  S(y,x)= 0.2866E+00
de standaardfout in het intercept                  S(a)= 0.1497E+00
de standaardfout in reg.coefficient b:             S(b)= 0.4756E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden                             t= 0.2182E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden                             t= 0.1362E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden                         SS(y)= 0.1730E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking                    SS(reg)= 0.1524E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad.              SS(res)= 0.2054E+01
```

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 3.000 | 1.300 |
| 2 | 4.000 | 2.550 |
| 3 | 3.100 | 1.550 |
| 4 | 2.250 | 1.200 |
| 5 | 4.350 | 2.500 |
| 6 | 2.200 | 0.950 |
| 7 | 1.450 | 0.750 |
| 8 | 2.000 | 1.050 |
| 9 | 2.850 | 1.600 |
| 10 | 2.950 | 1.350 |
| 11 | 1.100 | 0.500 |
| 12 | 1.300 | 0.150 |
| 13 | 2.000 | 0.600 |
| 14 | 3.600 | 1.900 |
| 15 | 3.150 | 1.850 |
| 16 | 2.650 | 1.450 |
| 17 | 2.250 | 1.300 |
| 18 | 4.100 | 1.900 |
| 19 | 1.800 | 0.900 |
| 20 | 4.750 | 3.250 |
| 21 | 5.400 | 3.600 |
| 22 | 2.650 | 1.950 |
| 23 | 5.350 | 2.600 |
| 24 | 2.500 | 1.200 |
| 25 | 4.000 | 1.950 |
| 26 | 2.650 | 1.600 |
| 27 | 1.600 | 0.850 |

Y=bX+a
b= 0.5961E+00
a=-0.2929E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9691E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2539E+00 |
| de standaardfout in het intercept | S(a)= 0.9303E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2643E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.3148E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2255E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3492E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.3279E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.2128E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.150 | 0.600 |
| 2 | 3.600 | 2.200 |
| 3 | 1.100 | 0.000 |
| 4 | 1.150 | 0.450 |
| 5 | 4.000 | 2.300 |
| 6 | 5.300 | 2.550 |
| 7 | 1.100 | 0.000 |
| 8 | 1.950 | 0.800 |
| 9 | 5.050 | 2.800 |
| 10 | 4.600 | 2.600 |
| 11 | 5.250 | 2.950 |
| 12 | 2.750 | 1.500 |
| 13 | 1.600 | 0.400 |
| 14 | 4.100 | 1.600 |
| 15 | 4.750 | 2.000 |
| 16 | 2.300 | 1.000 |
| 17 | 5.650 | 3.250 |
| 18 | 3.250 | 1.450 |
| 19 | 1.300 | 0.500 |
| 20 | 5.600 | 3.000 |
| 21 | 1.100 | 0.600 |
| 22 | 2.650 | 1.600 |
| 23 | 1.050 | 0.500 |
| 24 | 1.500 | 0.950 |
| 25 | 4.500 | 2.700 |
| 26 | 5.300 | 3.050 |
| 27 | 1.400 | 0.850 |
| 28 | 4.000 | 1.900 |
| 29 | 2.500 | 1.100 |
| 30 | 1.200 | 0.250 |
| 31 | 3.950 | 2.300 |
| 32 | 1.500 | 0.450 |
| 33 | 4.350 | 2.300 |
| 34 | 3.250 | 1.400 |
| 35 | 5.500 | 3.000 |

Y=bX+a
b= 0.5510E+00
a=-0.2772E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9864E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1241E+00 |
| de standaardfout in het intercept | S(a)= 0.5574E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1735E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.4972E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.3175E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1596E+02 |
| de kwadraatsom, toe te schrijven aan de regressievergelijking | SS(reg)= 0.1553E+02 |
| de kwadraatsom, toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.4312E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.000 | 0.800 |
| 2 | 4.100 | 2.100 |
| 3 | 4.600 | 2.150 |
| 4 | 2.350 | 0.800 |
| 5 | 4.900 | 2.450 |
| 6 | 0.600 | 0.400 |
| 7 | 3.400 | 1.750 |
| 8 | 1.350 | 0.500 |
| 9 | 4.700 | 2.250 |
| 10 | 4.750 | 2.250 |
| 11 | 3.000 | 1.500 |
| 12 | 4.650 | 2.300 |
| 13 | 1.750 | 0.500 |
| 14 | 3.500 | 1.600 |
| 15 | 4.200 | 1.900 |
| 16 | 1.600 | 0.600 |
| 17 | 3.100 | 1.450 |
| 18 | 1.950 | 0.750 |
| 19 | 4.500 | 2.200 |
| 20 | 1.000 | 0.100 |
| 21 | 3.200 | 1.500 |
| 22 | 1.100 | 0.400 |
| 23 | 3.900 | 2.000 |
| 24 | 3.800 | 1.950 |
| 25 | 3.250 | 1.500 |
| 26 | 2.950 | 1.450 |
| 27 | 0.850 | 0.150 |
| 28 | 2.850 | 1.400 |
| 29 | 1.350 | 0.300 |
| 30 | 2.800 | 1.200 |

Y=bX+a
b= 0.5521E+00
a=-0.2650E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9670E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1505E+00 |
| de standaardfout in het intercept | S(a)= 0.6349E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2700E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.4173E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2045E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1013E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.9470E+01 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.6569E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.800 | 1.350 |
| 2 | 1.800 | 0.900 |
| 3 | 0.700 | 0.250 |
| 4 | 1.800 | 0.850 |
| 5 | 0.450 | 0.050 |
| 6 | 3.100 | 1.250 |
| 7 | 0.500 | 0.000 |
| 8 | 3.000 | 1.400 |
| 9 | 1.950 | 0.800 |
| 10 | 3.350 | 1.600 |
| 11 | 1.950 | 0.600 |
| 12 | 3.400 | 1.700 |
| 13 | 3.700 | 1.900 |
| 14 | 3.000 | 1.400 |
| 15 | 2.600 | 1.300 |
| 16 | 1.250 | 0.400 |
| 17 | 2.700 | 1.250 |
| 18 | 0.750 | 0.300 |
| 19 | 1.800 | 0.500 |
| 20 | 2.850 | 1.300 |
| 21 | 2.150 | 0.900 |
| 22 | 3.300 | 1.500 |
| 23 | 0.550 | 0.000 |
| 24 | 2.950 | 1.000 |
| 25 | 2.000 | 0.600 |
| 26 | 0.750 | 0.150 |
| 27 | 2.500 | 1.500 |
| 28 | 1.300 | 0.400 |
| 29 | 3.100 | 1.600 |
| 30 | 3.100 | 1.400 |
| 31 | 0.800 | 0.050 |

Measurement A7

```
Y=bX+a
b= 0.5964E+00
a=-0.3770E+00
de correlatiecoefficient                          R= 0.9743E+00
de residuele standaardafwijking            S(y;x)= 0.2453E+00
de standaardfout in het intercept            S(a)= 0.8279E-01
de standaardfout in reg.coefficient b:       S(b)= 0.2517E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden                         t= 0.4554E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden                         t= 0.2369E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden                     SS(y)= 0.3559E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking                SS(reg)= 0.3378E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad.          SS(res)= 0.1806E+01
```

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.000 | 0.000 |
| 2 | 1.700 | 0.650 |
| 3 | 2.100 | 1.200 |
| 4 | 0.550 | 0.250 |
| 5 | 3.350 | 1.600 |
| 6 | 2.700 | 1.350 |
| 7 | 0.800 | 0.100 |
| 8 | 2.100 | 1.000 |
| 9 | 1.250 | 0.250 |
| 10 | 4.000 | 2.250 |
| 11 | 4.100 | 2.000 |
| 12 | 3.900 | 1.950 |
| 13 | 0.850 | 0.300 |
| 14 | 1.350 | 0.600 |
| 15 | 4.100 | 1.850 |
| 16 | 3.800 | 1.650 |
| 17 | 1.400 | 0.450 |
| 18 | 1.050 | 0.300 |
| 19 | 1.650 | 2.200 |
| 20 | 3.700 | 1.650 |
| 21 | 4.350 | 2.250 |
| 22 | 1.200 | 0.050 |
| 23 | 2.650 | 1.200 |
| 24 | 4.250 | 1.700 |
| 25 | 1.500 | 0.050 |
| 26 | 6.350 | 3.600 |
| 27 | 6.800 | 3.700 |
| 28 | 1.800 | 0.550 |
| 29 | 1.000 | 0.150 |
| 30 | 5.600 | 3.550 |
| 31 | 1.100 | 0.600 |
| 32 | 1.600 | 2.200 |

Y=bX+a
b= 0.5130E+00
a=-0.2225E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9349E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2433E+00 |
| de standaardfout in het intercept | S(a)= 0.1022E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.3680E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.2178E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.1394E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1316E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.1150E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.1657E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.700 | 1.000 |
| 2 | 0.600 | 0.000 |
| 3 | 3.100 | 1.300 |
| 4 | 3.400 | 2.050 |
| 5 | 1.350 | 0.400 |
| 6 | 4.500 | 1.600 |
| 7 | 1.800 | 0.400 |
| 8 | 1.000 | 0.100 |
| 9 | 4.350 | 1.800 |
| 10 | 4.150 | 1.400 |
| 11 | 1.350 | 0.600 |
| 12 | 1.100 | 0.250 |
| 13 | 4.650 | 2.150 |
| 14 | 2.150 | 0.750 |
| 15 | 3.150 | 1.450 |
| 16 | 1.750 | 0.500 |
| 17 | 4.150 | 2.200 |
| 18 | 2.750 | 1.100 |
| 19 | 3.200 | 1.700 |
| 20 | 1.500 | 0.550 |
| 21 | 3.350 | 1.400 |
| 22 | 1.250 | 0.450 |
| 23 | 1.050 | 0.300 |
| 24 | 3.000 | 1.400 |
| 25 | 2.950 | 1.800 |
| 26 | 1.000 | 0.350 |
| 27 | 2.800 | 1.450 |
| 28 | 3.100 | 1.600 |
| 29 | 3.150 | 1.550 |
| 30 | 0.650 | 0.200 |

Y=bX+a
b= 0.5763E+00
a=-0.2906E+00
de correlatiecoefficient R= 0.9861E+00
de residuele standaardafwijking S(y,x)= 0.1539E+00
de standaardfout in het intercept S(a)= 0.5756E-01
de standaardfout in reg.coefficient b: S(b)= 0.1836E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden t= 0.5048E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden t= 0.3140E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden SS(y)= 0.2401E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking SS(reg)= 0.2334E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad. SS(res)= 0.6630E+00

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.100 | 0.300 |
| 2 | 3.250 | 1.650 |
| 3 | 1.100 | 0.500 |
| 4 | 4.850 | 2.700 |
| 5 | 3.400 | 1.700 |
| 6 | 3.400 | 1.650 |
| 7 | 1.200 | 0.350 |
| 8 | 4.100 | 2.000 |
| 9 | 3.050 | 1.700 |
| 10 | 1.000 | 0.300 |
| 11 | 4.200 | 2.050 |
| 12 | 1.100 | 0.200 |
| 13 | 3.350 | 1.700 |
| 14 | 1.500 | 0.500 |
| 15 | 1.000 | 0.220 |
| 16 | 0.900 | 0.180 |
| 17 | 4.250 | 2.200 |
| 18 | 4.650 | 2.200 |
| 19 | 2.000 | 0.850 |
| 20 | 3.050 | 1.650 |
| 21 | 5.000 | 2.600 |
| 22 | 1.600 | 0.500 |
| 23 | 3.100 | 1.650 |
| 24 | 0.800 | 0.250 |
| 25 | 3.950 | 2.400 |
| 26 | 3.800 | 1.800 |
| 27 | 2.450 | 0.800 |
| 28 | 6.550 | 3.200 |
| 29 | 1.100 | 0.300 |
| 30 | 1.300 | 0.500 |

```
Y=bX+a
b= 0.5856E+00
a=-0.3699E+00
de correlatiecoefficient                                  R= 0.9414E+00
de residuele standaardafwijking                      S(y,x)= 0.2130E+00
de standaardfout in het intercept                      S(a)= 0.1122E+00
de standaardfout in reg.coefficient b:                 S(b)= 0.3895E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden                                 t= 0.3296E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden                                 t= 0.1504E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden                             SS(y)= 0.1157E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking                        SS(reg)= 0.1026E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad.                  SS(res)= 0.1316E+01
```

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.500 | 1.050 |
| 2 | 1.250 | 0.450 |
| 3 | 2.650 | 1.150 |
| 4 | 1.100 | 0.000 |
| 5 | 3.000 | 1.400 |
| 6 | 1.500 | 0.650 |
| 7 | 3.000 | 1.550 |
| 8 | 3.250 | 1.700 |
| 9 | 2.000 | 0.950 |
| 10 | 3.100 | 1.500 |
| 11 | 0.650 | 0.000 |
| 12 | 1.900 | 0.800 |
| 13 | 3.350 | 1.450 |
| 14 | 3.750 | 1.250 |
| 15 | 1.350 | 0.450 |
| 16 | 2.100 | 0.850 |
| 17 | 3.700 | 2.000 |
| 18 | 2.600 | 1.050 |
| 19 | 3.400 | 1.500 |
| 20 | 2.150 | 1.000 |
| 21 | 2.150 | 0.900 |
| 22 | 3.450 | 1.750 |
| 23 | 2.950 | 1.450 |
| 24 | 3.900 | 1.900 |
| 25 | 3.100 | 2.000 |
| 26 | 1.600 | 0.600 |
| 27 | 3.500 | 1.250 |
| 28 | 4.000 | 1.950 |
| 29 | 3.800 | 1.850 |
| 30 | 2.300 | 0.600 |
| 31 | 4.900 | 2.700 |

Y=bX+a
b= 0.5460E+00
a=-0.3507E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9896E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1323E+00 |
| de standaardfout in het intercept | S(a)= 0.5475E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1501E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.6405E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.3638E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.2366E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.2317E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.4904E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.000 | 0.000 |
| 2 | 2.350 | 0.700 |
| 3 | 2.600 | 0.850 |
| 4 | 6.100 | 2.950 |
| 5 | 4.000 | 1.700 |
| 6 | 1.800 | 0.600 |
| 7 | 1.650 | 0.500 |
| 8 | 4.450 | 2.200 |
| 9 | 0.900 | 0.200 |
| 10 | 4.400 | 2.200 |
| 11 | 4.800 | 2.400 |
| 12 | 2.050 | 0.950 |
| 13 | 4.350 | 2.150 |
| 14 | 3.850 | 1.600 |
| 15 | 1.350 | 0.450 |
| 16 | 4.750 | 2.300 |
| 17 | 2.000 | 0.850 |
| 18 | 2.000 | 0.850 |
| 19 | 5.600 | 2.600 |
| 20 | 5.700 | 2.800 |
| 21 | 1.300 | 0.450 |
| 22 | 2.950 | 1.100 |
| 23 | 5.200 | 2.600 |
| 24 | 2.300 | 0.850 |
| 25 | 4.850 | 2.450 |
| 26 | 1.500 | 0.450 |
| 27 | 4.650 | 2.050 |
| 28 | 3.700 | 1.650 |
| 29 | 4.950 | 2.200 |
| 30 | 1.100 | 0.450 |

Y=bX+a
b= 0.6121E+00
a=-0.3886E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9684E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2754E+00 |
| de standaardfout in het intercept | S(a)= 0.1114E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2982E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.3489E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2053E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3408E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(res)= 0.3195E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.2123E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 5.650 | 3.200 |
| 2 | 1.000 | 0.000 |
| 3 | 4.250 | 2.500 |
| 4 | 1.200 | 0.700 |
| 5 | 3.850 | 2.000 |
| 6 | 1.000 | 0.050 |
| 7 | 3.400 | 1.600 |
| 8 | 3.400 | 2.900 |
| 9 | 3.200 | 1.450 |
| 10 | 5.200 | 2.700 |
| 11 | 0.800 | 0.000 |
| 12 | 4.950 | 2.600 |
| 13 | 2.150 | 0.900 |
| 14 | 4.600 | 2.250 |
| 15 | 4.000 | 2.050 |
| 16 | 4.350 | 2.350 |
| 17 | 5.900 | 3.000 |
| 18 | 0.800 | 0.250 |
| 19 | 3.000 | 1.600 |
| 20 | 1.750 | 0.600 |
| 21 | 5.750 | 3.000 |
| 22 | 1.600 | 0.550 |
| 23 | 1.400 | 0.400 |
| 24 | 4.400 | 2.200 |
| 25 | 4.500 | 2.450 |
| 26 | 2.150 | 0.750 |
| 27 | 5.700 | 3.000 |
| 28 | 2.200 | 0.800 |
| 29 | 2.100 | 0.650 |
| 30 | 5.750 | 3.050 |

Y=bX+a
b= 0.7921E+00
a=-0.3903E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9801E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2304E+00 |
| de standaardfout in het intercept | S(a)= 0.1169E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.3031E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.3339E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2613E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3774E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.3626E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.1486E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.600 | 1.550 |
| 2 | 4.650 | 3.550 |
| 3 | 3.100 | 2.150 |
| 4 | 2.350 | 1.900 |
| 5 | 4.800 | 3.250 |
| 6 | 3.650 | 2.650 |
| 7 | 5.100 | 3.500 |
| 8 | 3.100 | 2.200 |
| 9 | 4.150 | 2.900 |
| 10 | 6.950 | 5.000 |
| 11 | 6.100 | 4.100 |
| 12 | 3.450 | 2.400 |
| 13 | 2.100 | 1.100 |
| 14 | 3.950 | 3.000 |
| 15 | 4.550 | 3.200 |
| 16 | 2.550 | 1.350 |
| 17 | 3.850 | 2.700 |
| 18 | 4.050 | 2.800 |
| 19 | 4.000 | 2.350 |
| 20 | 2.400 | 1.200 |
| 21 | 5.300 | 3.850 |
| 22 | 2.500 | 1.750 |
| 23 | 1.100 | 0.200 |
| 24 | 0.450 | 0.100 |
| 25 | 4.100 | 3.250 |
| 26 | 2.700 | 1.950 |
| 27 | 1.850 | 0.800 |
| 28 | 4.600 | 3.600 |
| 29 | 3.600 | 2.350 |
| 30 | 4.300 | 3.100 |

```
Y=bX+a
b= 0.7545E+00
a=-0.4326E+00
de correlatiecoefficient                          R= 0.9694E+00
de residuele standaardafwijking            S(y,x)= 0.3110E+00
de standaardfout in het intercept            S(a)= 0.1293E+00
de standaardfout in reg.coefficient b:       S(b)= 0.3489E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden                         t= 0.3345E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden                         t= 0.2162E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden                   SS(y)= 0.4814E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking              SS(reg)= 0.4524E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad.        SS(res)= 0.2902E+01
```

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 5.400 | 4.000 |
| 2 | 5.150 | 3.200 |
| 3 | 4.350 | 2.850 |
| 4 | 1.350 | 0.550 |
| 5 | 1.000 | 0.650 |
| 6 | 1.100 | 0.700 |
| 7 | 4.000 | 2.750 |
| 8 | 4.200 | 3.000 |
| 9 | 4.400 | 2.800 |
| 10 | 3.400 | 1.650 |
| 11 | 3.650 | 1.800 |
| 12 | 4.100 | 2.000 |
| 13 | 4.750 | 3.250 |
| 14 | 6.000 | 4.350 |
| 15 | 0.750 | 0.000 |
| 16 | 4.500 | 2.250 |
| 17 | 4.000 | 2.750 |
| 18 | 3.950 | 2.600 |
| 19 | 3.000 | 2.200 |
| 20 | 0.700 | 0.000 |
| 21 | 4.000 | 2.950 |
| 22 | 1.350 | 0.450 |
| 23 | 4.350 | 3.150 |
| 24 | 1.350 | 0.600 |
| 25 | 1.750 | 0.850 |
| 26 | 2.500 | 1.750 |
| 27 | 5.300 | 3.750 |
| 28 | 2.050 | 1.200 |
| 29 | 3.600 | 2.300 |
| 30 | 2.000 | 1.150 |
| 31 | 6.250 | 4.300 |
| 32 | 3.100 | 1.350 |

Y=bX+a
b= 0.6955E+00
a=-0.5164E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9183E+00 |
| de residuele standaardafwijking | S(y,x)= 0.4113E+00 |
| de standaardfout in het intercept | S(a)= 0.1725E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.5666E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.2994E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.1227E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3022E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.2548E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.4736E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 0.700 | 0.300 |
| 2 | 4.600 | 2.500 |
| 3 | 3.600 | 1.450 |
| 4 | 1.100 | 0.450 |
| 5 | 2.250 | 1.050 |
| 6 | 0.950 | 0.730 |
| 7 | 2.500 | 1.100 |
| 8 | 1.050 | 0.050 |
| 9 | 4.600 | 2.200 |
| 10 | 2.150 | 0.700 |
| 11 | 3.500 | 1.400 |
| 12 | 4.000 | 1.850 |
| 13 | 2.800 | 1.050 |
| 14 | 3.800 | 1.650 |
| 15 | 3.350 | 1.450 |
| 16 | 0.550 | 0.000 |
| 17 | 2.050 | 0.650 |
| 18 | 1.200 | 0.200 |
| 19 | 2.200 | 1.000 |
| 20 | 3.750 | 2.700 |
| 21 | 3.250 | 2.050 |
| 22 | 1.100 | 0.000 |
| 23 | 1.050 | 0.000 |
| 24 | 3.200 | 1.500 |
| 25 | 5.100 | 3.700 |
| 26 | 3.750 | 2.650 |
| 27 | 2.150 | 1.050 |
| 28 | 3.100 | 2.350 |
| 29 | 4.050 | 3.100 |
| 30 | 4.750 | 2.800 |

Y=bX+a

b= 0.7341E+00
a=-0.4941E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.7621E+00 |
| de residuele standaardafwijking | S(y,x)= 0.4976E+00 |
| de standaardfout in het intercept | S(a)= 0.2357E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1123E+00 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.2096E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.6447E+01 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1772E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.1029E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.7430E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.750 | 0.600 |
| 2 | 0.800 | 0.000 |
| 3 | 1.600 | 0.550 |
| 4 | 1.250 | 0.000 |
| 5 | 3.800 | 1.250 |
| 6 | 2.100 | 0.500 |
| 7 | 0.850 | 0.550 |
| 8 | 2.600 | 1.050 |
| 9 | 1.900 | 0.600 |
| 10 | 1.750 | 1.050 |
| 11 | 2.900 | 1.050 |
| 12 | 1.150 | 0.100 |
| 13 | 2.250 | 1.950 |
| 14 | 1.600 | 0.550 |
| 15 | 2.400 | 0.700 |
| 16 | 1.150 | 0.350 |
| 17 | 2.600 | 1.800 |
| 18 | 0.850 | 0.450 |
| 19 | 4.100 | 3.550 |
| 20 | 2.000 | 1.600 |
| 21 | 1.600 | 0.300 |
| 22 | 1.650 | 1.350 |
| 23 | 2.100 | 0.800 |
| 24 | 1.800 | 1.300 |
| 25 | 2.350 | 1.350 |
| 26 | 1.550 | 0.350 |
| 27 | 2.650 | 0.550 |
| 28 | 2.100 | 1.400 |
| 29 | 1.100 | 0.100 |
| 30 | 2.400 | 1.700 |
| 31 | 0.900 | 0.000 |
| 32 | 2.700 | 1.850 |

```
Y=bX+a
b= 0.7765E+00
a=-0.4644E+00
de correlatiecoefficient                           R= 0.9875E+00
de residuele standaardafwijking               S(y,x)= 0.2144E+00
de standaardfout in het intercept               S(a)= 0.8651E-01
de standaardfout in reg.coefficient b:          S(b)= 0.2298E-01
toetsing voor het intercept a,
met (N-2) vrijheidsgraden                          t= 0.5368E+01
toetsing voor regressiecoefficient b
met (N-2) vrijheidsgraden                          t= 0.3379E+02
de totale kwadraatsom
met (N-1) vrijheidsgraden                      SS(y)= 0.5384E+02
de kwadraatsom,toe te schrijven
aan de regressievergelijking                 SS(reg)= 0.5251E+02
de kwadraatsom,toe te schrijven
aan afwijkingen van de regressie-
vergelijking met (N-2) vrijh.grad.           SS(res)= 0.1333E+01
```

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 0.600 | 0.000 |
| 2 | 4.400 | 3.000 |
| 3 | 1.550 | 0.900 |
| 4 | 4.750 | 3.400 |
| 5 | 5.200 | 3.400 |
| 6 | 1.650 | 0.800 |
| 7 | 6.300 | 4.050 |
| 8 | 2.400 | 1.200 |
| 9 | 3.750 | 2.500 |
| 10 | 1.700 | 0.900 |
| 11 | 3.500 | 2.000 |
| 12 | 5.400 | 3.900 |
| 13 | 5.250 | 3.850 |
| 14 | 1.600 | 0.800 |
| 15 | 1.750 | 0.900 |
| 16 | 4.100 | 2.800 |
| 17 | 2.550 | 1.500 |
| 18 | 2.050 | 1.000 |
| 19 | 3.550 | 2.350 |
| 20 | 4.000 | 2.600 |
| 21 | 5.000 | 2.950 |
| 22 | 1.600 | 1.000 |
| 23 | 2.500 | 1.150 |
| 24 | 6.050 | 4.200 |
| 25 | 6.550 | 4.550 |
| 26 | 1.700 | 0.700 |
| 27 | 3.650 | 2.750 |
| 28 | 2.550 | 1.500 |
| 29 | 5.300 | 4.200 |
| 30 | 2.600 | 1.700 |
| 31 | 0.950 | 0.200 |

Y=bX+a
b= 0.7798E+00
a=-0.3844E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9731E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2854E+00 |
| de standaardfout in het intercept | S(a)= 0.1036E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.3486E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.3711E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2237E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.4303E+02 |
| de kwadraatsom, toe te schrijven aan de regressievergelijking | SS(reg)= 0.4075E+02 |
| de kwadraatsom, toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.2280E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.050 | 0.500 |
| 2 | 2.900 | 2.000 |
| 3 | 3.600 | 2.650 |
| 4 | 3.750 | 2.900 |
| 5 | 1.550 | 0.800 |
| 6 | 1.350 | 0.700 |
| 7 | 1.800 | 0.650 |
| 8 | 1.500 | 0.600 |
| 9 | 3.250 | 2.100 |
| 10 | 1.000 | 0.450 |
| 11 | 2.400 | 1.650 |
| 12 | 2.400 | 1.750 |
| 13 | 0.650 | 0.000 |
| 14 | 3.500 | 2.900 |
| 15 | 0.700 | 0.150 |
| 16 | 3.400 | 1.900 |
| 17 | 0.850 | 0.400 |
| 18 | 4.100 | 2.850 |
| 19 | 1.250 | 0.600 |
| 20 | 4.350 | 2.800 |
| 21 | 0.900 | 0.000 |
| 22 | 4,600 | 3.200 |
| 23 | 5.500 | 2.950 |
| 24 | 1.600 | 0.600 |
| 25 | 4.000 | 3.100 |
| 26 | 1.000 | 0.500 |
| 27 | 5.750 | 4.250 |
| 28 | 1.050 | 0.400 |
| 29 | 4.000 | 2.900 |
| 30 | 3.300 | 2.300 |

Y=bX+a
b= 0.4498E+00
a=-0.1685E+00

| | | |
|---|---|---|
| de correlatiecoefficient | R= | 0.9582E+00 |
| de residuele standaardafwijking | S(y,x)= | 0.1963E+00 |
| de standaardfout in het intercept | S(a)= | 0.8239E-01 |
| de standaardfout in reg.coefficient b: | S(b)= | 0.2585E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= | 0.2045E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= | 0.1740E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= | 0.1271E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= | 0.1167E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= | 0.1040E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.000 | 0.050 |
| 2 | 3.000 | 1.250 |
| 3 | 4.250 | 1.600 |
| 4 | 2.400 | 0.800 |
| 5 | 1.800 | 0.650 |
| 6 | 4.400 | 1.750 |
| 7 | 2.750 | 1.150 |
| 8 | 1.500 | 0.450 |
| 9 | 4.350 | 1.750 |
| 10 | 3.100 | 1.050 |
| 11 | 1.650 | 0.450 |
| 12 | 2.250 | 1.000 |
| 13 | 4.500 | 2.350 |
| 14 | 2.350 | 0.850 |
| 15 | 4.350 | 2.150 |
| 16 | 1.350 | 0.550 |
| 17 | 2.450 | 0.900 |
| 18 | 5.400 | 2.000 |
| 19 | 3.150 | 1.050 |
| 20 | 2.100 | 0.600 |
| 21 | 6.300 | 2.400 |
| 22 | 0.900 | 0.200 |
| 23 | 5.300 | 2.350 |
| 24 | 2.000 | 0.700 |
| 25 | 1.300 | 0.600 |
| 26 | 2.950 | 1.350 |
| 27 | 2.500 | 0.800 |
| 28 | 1.250 | 0.350 |
| 29 | 2.300 | 1.250 |

Y=bX+a
b= 0.4494E+00
a=-0.2160E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9700E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1644E+00 |
| de standaardfout in het intercept | S(a)= 0.7060E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2093E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.3059E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2148E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1324E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(res)= 0.1246E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.7835E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 5.950 | 2.350 |
| 2 | 2.500 | 0.700 |
| 3 | 5.950 | 2.050 |
| 4 | 4.200 | 1.500 |
| 5 | 4.000 | 1.600 |
| 6 | 2.700 | 1.000 |
| 7 | 0.750 | 0.000 |
| 8 | 3.000 | 1.200 |
| 9 | 3.300 | 1.250 |
| 10 | 3.100 | 1.300 |
| 11 | 1.500 | 0.500 |
| 12 | 1.850 | 0.700 |
| 13 | 1.700 | 0.600 |
| 14 | 0.600 | 0.000 |
| 15 | 2.350 | 1.000 |
| 16 | 4.850 | 2.000 |
| 17 | 1.650 | 0.400 |
| 18 | 3.050 | 1.050 |
| 19 | 4.500 | 1.900 |
| 20 | 4.700 | 2.050 |
| 21 | 4.250 | 1.800 |
| 22 | 1.400 | 0.150 |
| 23 | 3.950 | 1.550 |
| 24 | 4.000 | 1.600 |
| 25 | 0.900 | 0.000 |
| 26 | 4.250 | 1.750 |
| 27 | 3.500 | 1.650 |
| 28 | 2.100 | 0.650 |
| 29 | 3.500 | 1.550 |
| 30 | 3.100 | 1.150 |
| 31 | 1.850 | 1.000 |

Y=bX+a
b= 0.4719E+00
a=-0.3843E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.8582E+00 |
| de residuele standaardafwijking | S(y,x)= 0.3516E+00 |
| de standaardfout in het intercept | S(a)= 0.1722E+00 |
| de standaardfout in reg.coefficient b: | S(b)= 0.5242E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.2232E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.9003E+01 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1361E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.1002E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.3585E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 4.200 | 1.800 |
| 2 | 5.050 | 1.700 |
| 3 | 5.000 | 1.700 |
| 4 | 2.050 | 0.500 |
| 5 | 4.400 | 2.000 |
| 6 | 1.000 | 0.000 |
| 7 | 2.250 | 0.750 |
| 8 | 6.100 | 2.750 |
| 9 | 2.650 | 1.000 |
| 10 | 4.000 | 1.650 |
| 11 | 2.500 | 0.900 |
| 12 | 2.600 | 1.000 |
| 13 | 1.650 | 0.300 |
| 14 | 2.850 | 1.000 |
| 15 | 3.500 | 1.600 |
| 16 | 1.750 | 1.100 |
| 17 | 3.750 | 2.600 |
| 18 | 2.000 | 0.650 |
| 19 | 1.750 | 0.400 |
| 20 | 3.500 | 1.250 |
| 21 | 1.400 | 0.350 |
| 22 | 2.800 | 0.600 |
| 23 | 1.750 | 0.000 |
| 24 | 4.800 | 1.250 |
| 25 | 3.500 | 1.000 |
| 26 | 3.300 | 1.000 |
| 27 | 3.000 | 1.000 |
| 28 | 2.050 | 0.400 |
| 29 | 2.800 | 0.600 |
| 30 | 2.750 | 0.700 |
| 31 | 4.050 | 1.250 |

Y=bX+a
b= 0.3214E+00
a=-0.4889E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9618E+00 |
| de residuele standaardafwijking | S(y,x)= 0.9965E-01 |
| de standaardfout in het intercept | S(a)= 0.6277E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1728E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.7790E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.1860E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3713E+01 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.3435E+01 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.2781E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.850 | 0.300 |
| 2 | 4.650 | 1.100 |
| 3 | 4.050 | 0.950 |
| 4 | 4.050 | 0.800 |
| 5 | 2.850 | 0.400 |
| 6 | 2.500 | 0.250 |
| 7 | 4.050 | 0.900 |
| 8 | 3.250 | 0.600 |
| 9 | 1.600 | 0.000 |
| 10 | 2.600 | 0.400 |
| 11 | 3.000 | 0.450 |
| 12 | 3.100 | 0.550 |
| 13 | 3.750 | 0.800 |
| 14 | 2.600 | 0.300 |
| 15 | 2.950 | 0.450 |
| 16 | 1.600 | 0.000 |
| 17 | 3.200 | 0.600 |
| 18 | 5.000 | 1.150 |
| 19 | 4.150 | 0.850 |
| 20 | 3.900 | 0.800 |
| 21 | 3.750 | 0.800 |
| 22 | 5.000 | 1.200 |
| 23 | 5.900 | 1.350 |
| 24 | 3.000 | 0.250 |
| 25 | 5.200 | 1.000 |
| 26 | 4.100 | 0.550 |
| 27 | 3.650 | 0.750 |
| 28 | 1.300 | 0.000 |
| 29 | 3.600 | 0.700 |
| 30 | 3.100 | 0.600 |

Measurement C2

Y=bX+a
b= 0.2486E+00
a=-0.4457E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.8611E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1763E+00 |
| de standaardfout in het intercept | S(a)= 0.9980E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2726E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.4465E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.9122E+01 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.3488E+01 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.2586E+01 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.9013E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 3.100 | 0.200 |
| 2 | 2.950 | 0.050 |
| 3 | 2.750 | 0.100 |
| 4 | 1.900 | 0.000 |
| 5 | 2.150 | 0.000 |
| 6 | 2.950 | 0.450 |
| 7 | 1.950 | 0.200 |
| 8 | 2.900 | 0.400 |
| 9 | 3.750 | 0.600 |
| 10 | 2.500 | 0.200 |
| 11 | 4.000 | 0.700 |
| 12 | 2.100 | 0.000 |
| 13 | 4.300 | 0.800 |
| 14 | 1.600 | 0.000 |
| 15 | 4.500 | 1.000 |
| 16 | 2.150 | 0.200 |
| 17 | 5.450 | 1.100 |
| 18 | 3.500 | 0.500 |
| 19 | 5.250 | 1.050 |
| 20 | 3.650 | 0.600 |
| 21 | 4.100 | 0.750 |
| 22 | 5.600 | 1.000 |
| 23 | 5.700 | 0.700 |
| 24 | 4.750 | 0.500 |
| 25 | 2.400 | 0.000 |
| 26 | 3.650 | 0.450 |
| 27 | 3.150 | 0.350 |
| 28 | 4.000 | 0.250 |
| 29 | 4.700 | 0.400 |
| 30 | 4.000 | 0.300 |
| 31 | 2.200 | 0.100 |

Y=bX+a
b= 0.4136E+00
a=-0.6504E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9819E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1092E+00 |
| de standaardfout in het intercept | S(a)= 0.6222E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1506E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.1045E+02 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2746E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.9327E+01 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.8994E+01 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressievergelijking met (N-2) vrijh.grad. | SS(res)= 0.3339E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 3.350 | 0.700 |
| 2 | 3.100 | 0.600 |
| 3 | 4.500 | 1.300 |
| 4 | 4.750 | 1.300 |
| 5 | 1.650 | 0.000 |
| 6 | 3.700 | 0.800 |
| 7 | 1.600 | 0.000 |
| 8 | 4.600 | 1.200 |
| 9 | 4.700 | 1.400 |
| 10 | 4.250 | 1.150 |
| 11 | 1.850 | 0.100 |
| 12 | 5.900 | 1.850 |
| 13 | 4.150 | 0.950 |
| 14 | 2.600 | 0.150 |
| 15 | 5.500 | 1.500 |
| 16 | 5.000 | 1.200 |
| 17 | 5.000 | 1.400 |
| 18 | 4.650 | 1.200 |
| 19 | 3.250 | 0.850 |
| 20 | 4.550 | 1.250 |
| 21 | 5.300 | 1.500 |
| 22 | 4.150 | 1.250 |
| 23 | 1.600 | 0.050 |
| 24 | 4.150 | 1.100 |
| 25 | 5.500 | 1.650 |
| 26 | 2.000 | 0.100 |
| 27 | 4.500 | 1.300 |
| 28 | 5.100 | 1.600 |
| 29 | 1.450 | 0.150 |
| 30 | 5.000 | 1.450 |

Y=bX+a
b= 0.4800E+00
a=-0.4935E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9914E+00 |
| de residuele standaardafwijking | S(y,x)= 0.9774E-01 |
| de standaardfout in het intercept | S(a)= 0.4054E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1177E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.1217E+02 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.4078E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1616E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.1588E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.2770E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 3.000 | 1.100 |
| 2 | 4.800 | 1.850 |
| 3 | 3.600 | 1.200 |
| 4 | 1.050 | 0.000 |
| 5 | 2.000 | 0.500 |
| 6 | 1.700 | 0.350 |
| 7 | 5.450 | 2.300 |
| 8 | 3.750 | 1.300 |
| 9 | 2.650 | 0.850 |
| 10 | 4.150 | 1.600 |
| 11 | 1.400 | 0.050 |
| 12 | 6.600 | 2.700 |
| 13 | 4.700 | 1.650 |
| 14 | 3.100 | 1.000 |
| 15 | 1.750 | 0.450 |
| 16 | 1.250 | 0.000 |
| 17 | 4.400 | 1.500 |
| 18 | 3.100 | 0.850 |
| 19 | 2.000 | 0.350 |
| 20 | 1.100 | 0.000 |
| 21 | 2.150 | 0.700 |
| 22 | 3.400 | 1.250 |
| 23 | 1.200 | 0.000 |
| 24 | 5.100 | 1.850 |
| 25 | 1.500 | 0.300 |
| 26 | 2.850 | 1.000 |
| 27 | 5.500 | 2.000 |
| 28 | 2.000 | 0.450 |
| 29 | 4.000 | 1.400 |
| 30 | 2.500 | 0.700 |
| 31 | 4.500 | 1.650 |

Measurement D2

Y=bX+a
b= 0.6835E+00
a=-0.4853E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9960E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1184E+00 |
| de standaardfout in het intercept | S(a)= 0.4139E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1140E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.1172E+02 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.5996E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.5084E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.5043E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.4068E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 4.050 | 2.300 |
| 2 | 3.350 | 1.850 |
| 3 | 0.750 | 0.000 |
| 4 | 0.800 | 0.250 |
| 5 | 5.750 | 3.450 |
| 6 | 1.350 | 0.250 |
| 7 | 3.000 | 1.700 |
| 8 | 1.000 | 0.350 |
| 9 | 2.100 | 1.000 |
| 10 | 3.650 | 2.200 |
| 11 | 5.250 | 3.200 |
| 12 | 4.150 | 2.500 |
| 13 | 4.650 | 2.650 |
| 14 | 0.600 | 0.050 |
| 15 | 1.250 | 0.200 |
| 16 | 5.750 | 3.450 |
| 17 | 4.950 | 2.700 |
| 18 | 1.350 | 0.450 |
| 19 | 2.150 | 1.000 |
| 20 | 5.450 | 3.250 |
| 21 | 4.850 | 2.900 |
| 22 | 1.850 | 0.650 |
| 23 | 6.100 | 3.650 |
| 24 | 2.100 | 0.800 |
| 25 | 6.350 | 3.800 |
| 26 | 4.100 | 2.150 |
| 27 | 1.800 | 0.750 |
| 28 | 1.050 | 0.350 |
| 29 | 1.250 | 0.300 |
| 30 | 4.750 | 2.800 |
| 31 | 1.000 | 0.000 |

Measurement D3

Y=bX+a
b= 0.4844E+00
a=-0.3885E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9883E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1231E+00 |
| de standaardfout in het intercept | S(a)= 0.4406E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.1368E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.8817E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.3542E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.1946E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.1901E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.4545E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 4.200 | 1.650 |
| 2 | 1.300 | 0.000 |
| 3 | 3.800 | 1.450 |
| 4 | 4.950 | 1.950 |
| 5 | 2.900 | 0.950 |
| 6 | 4.000 | 1.550 |
| 7 | 1.500 | 0.100 |
| 8 | 5.000 | 2.000 |
| 9 | 1.100 | 0.100 |
| 10 | 3.250 | 1.150 |
| 11 | 1.650 | 0.500 |
| 12 | 3.150 | 0.900 |
| 13 | 0.800 | 0.000 |
| 14 | 1.250 | 0.050 |
| 15 | 4.200 | 1.850 |
| 16 | 1.000 | 0.100 |
| 17 | 3.250 | 1.250 |
| 18 | 1.100 | 0.200 |
| 19 | 0.800 | 0.000 |
| 20 | 2.350 | 0.800 |
| 21 | 5.000 | 2.150 |
| 22 | 6.100 | 2.400 |
| 23 | 1.500 | 0.550 |
| 24 | 4.700 | 1.900 |
| 25 | 5.950 | 2.550 |
| 26 | 1.350 | 0.400 |
| 27 | 3.600 | 1.300 |
| 28 | 1.600 | 0.400 |
| 29 | 2.300 | 0.650 |
| 30 | 3.250 | 1.400 |
| 31 | 1.150 | 0.300 |
| 32 | 1.600 | 0.450 |

Y=bX+a
b= 0.6566E+00
a=-0.5075E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9767E+00 |
| de residuele standaardafwijking | S(y,x)= 0.2482E+00 |
| de standaardfout in het intercept | S(a)= 0.9951E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2634E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.5100E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.2493E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.4012E+02 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.3828E+02 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.1848E+01 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 1.850 | 0.750 |
| 2 | 4.750 | 2.750 |
| 3 | 1.100 | 0.300 |
| 4 | 4.600 | 2.400 |
| 5 | 2.100 | 0.800 |
| 6 | 4.700 | 2.800 |
| 7 | 1.600 | 0.500 |
| 8 | 2.250 | 0.850 |
| 9 | 2.400 | 1.000 |
| 10 | 2.100 | 0.750 |
| 11 | 5.500 | 3.350 |
| 12 | 3.250 | 1.400 |
| 13 | 1.500 | 0.350 |
| 14 | 2.600 | 1.150 |
| 15 | 5.250 | 3.100 |
| 16 | 2.000 | 0.950 |
| 17 | 1.500 | 0.600 |
| 18 | 4.650 | 2.600 |
| 19 | 3.850 | 1.800 |
| 20 | 3.000 | 1.650 |
| 21 | 2.500 | 1.150 |
| 22 | 1.450 | 0.350 |
| 23 | 5.100 | 2.900 |
| 24 | 3.000 | 0.800 |
| 25 | 1.850 | 0.700 |
| 26 | 6.600 | 4.200 |
| 27 | 5.950 | 3.550 |
| 28 | 2.350 | 1.150 |
| 29 | 6.500 | 3.100 |
| 30 | 2.100 | 1.400 |
| 31 | 6.100 | 3.250 |
| 32 | 4.450 | 2.600 |

Y=bX+a
b= 0.4291E+00
a=-0.4957E+00

| | |
|---|---|
| de correlatiecoefficient | R= 0.9614E+00 |
| de residuele standaardafwijking | S(y,x)= 0.1182E+00 |
| de standaardfout in het intercept | S(a)= 0.5967E-01 |
| de standaardfout in reg.coefficient b: | S(b)= 0.2320E-01 |
| toetsing voor het intercept a, met (N-2) vrijheidsgraden | t= 0.8308E+01 |
| toetsing voor regressiecoefficient b met (N-2) vrijheidsgraden | t= 0.1850E+02 |
| de totale kwadraatsom met (N-1) vrijheidsgraden | SS(y)= 0.5172E+01 |
| de kwadraatsom,toe te schrijven aan de regressievergelijking | SS(reg)= 0.4780E+01 |
| de kwadraatsom,toe te schrijven aan afwijkingen van de regressie-vergelijking met (N-2) vrijh.grad. | SS(res)= 0.3912E+00 |

De ingevoerde punten zijn:

| n | X-waarde | Y-waarde |
|---|---|---|
| 1 | 2.500 | 0.850 |
| 2 | 2.450 | 0.650 |
| 3 | 1.900 | 0.250 |
| 4 | 1.300 | 0.000 |
| 5 | 2.600 | 0.700 |
| 6 | 1.050 | 0.000 |
| 7 | 1.600 | 0.150 |
| 8 | 2.150 | 0.550 |
| 9 | 2.150 | 0.450 |
| 10 | 1.150 | 0.000 |
| 11 | 2.750 | 0.800 |
| 12 | 2.250 | 0.500 |
| 13 | 2.350 | 0.600 |
| 14 | 2.050 | 0.250 |
| 15 | 2.750 | 0.600 |
| 16 | 3.750 | 1.050 |
| 17 | 2.350 | 0.600 |
| 18 | 2.450 | 0.650 |
| 19 | 2.750 | 0.550 |
| 20 | 0.850 | 0.000 |
| 21 | 1.350 | 0.000 |
| 22 | 3.250 | 0.700 |
| 23 | 3.600 | 0.850 |
| 24 | 1.350 | 0.000 |
| 25 | 3.750 | 1.250 |
| 26 | 5.000 | 1.750 |
| 27 | 3.600 | 1.000 |
| 28 | 2.400 | 0.600 |
| 29 | 1.500 | 0.000 |
| 30 | 3.000 | 0.650 |

APPENDIX 2

List of references 01

01 IHVE Guide - The institution of Heating and Ventilating Engineers London, 1972 Book A,B and C (T.H.D.)

02 Physikhütte - Band 1, Mechanik 29. Auflage

03 ir.L.A.van de Putte - Stroming en Warmteoverdracht I Delft 1976

04 Gauger R.und Schüle W - Lüftungsanlagen im Wohnungsbau FBW (veröffentlichung der Forschungsgemeinschaft Bauen und Wohnen) Stuttgart Oktober 1958

05 Alink A en Veldkamp RG - Lineaire Regressie, uit handleiding voor TI 54 Lab. Gezondheidstechniek juni 1980

06 Ashworth J. - The Dar es Salaam ventilated improved pit latrine demonstration project. Ministry of Lands, Housing and Urban Development Dar es Salaam, February 1981, Tanzania.

07 Kalbermatten John M. - De Anne S.Julius and Charles G.Gunnerson Appropriate Technology for Water Supply and Sanitation Vol.1 Technical and Economic Options World Bank December 1980

08 Curtis C.F. and P.M. Hawkins - Entomological studies of on-site sanitation systems in Botswana and Tanzania. Transactions of the Royal Society of Tropical Medicine and Hygiene, Vol.76, No.1, 1982.

09 - NEN 1087 December 1975 Ventilatie van woongebouwen

10 - BS 5925: 1980 British Standards Institution Design of buildings: ventilation principles and designing for natural ventilation.

11 - IS: 3362 - 1965 Indian Standards Institution Code of practice for natural ventilation of residential buildings.

12 - AS 1668, Part 2-1980 Australian Standards SAA Mechanical Ventilation and Airconditioning Code Part 2 Ventilation Requirements.

13 Terje Bodoegaard - Climate and Design in Tanzania Guidelines for rural housing B.R.U. - Ardhi Ministry Dar es Salaam 1981

List of references 02

14 Roedler F. – Zur problematik der Lüftung innenliegender Aborte und Bäder im sozialen Wohnungsbau. Ges.Ing. 72 (1951, Nr 1/2, S. 8 und Nr.4, S.58

15 Back O. – Die Ermittlung der relativen Wertigkeit windbetätiger Saughauben. Ges.-Ing. 55 (1932), Nr.51 S.607

16 de Voogd und Wirtz – Betrachtungen über das verhalten von Schornsteinaufsätzen bei Wind und Regen Ges-Ing. 59 (1936) Nr. 42, S.605 u.Nr.43,S621

17 ter Linden – Schornstein- und Lüftungsaufsätze. Ges.Ing. 62 (1939) S.221

18 H.Föttinger – Strömung in dampfkesselanlagen VGB Heft 73 10 sept. 1939

19 W.G. Cornell – Losses in flow normal to plane screens Transactions of the American Society of Mechanical Eng. 80 (4) 791-799 (1958)

20 E.P.Box, W.G.Hunter – J.Stuart Hunter Statistics for experimenters An introduction to Design, Data analysis, and Model Building. 1978 J.Wiley and Sons, Inc.

APPENDIX 3

Day-programme and weather conditions

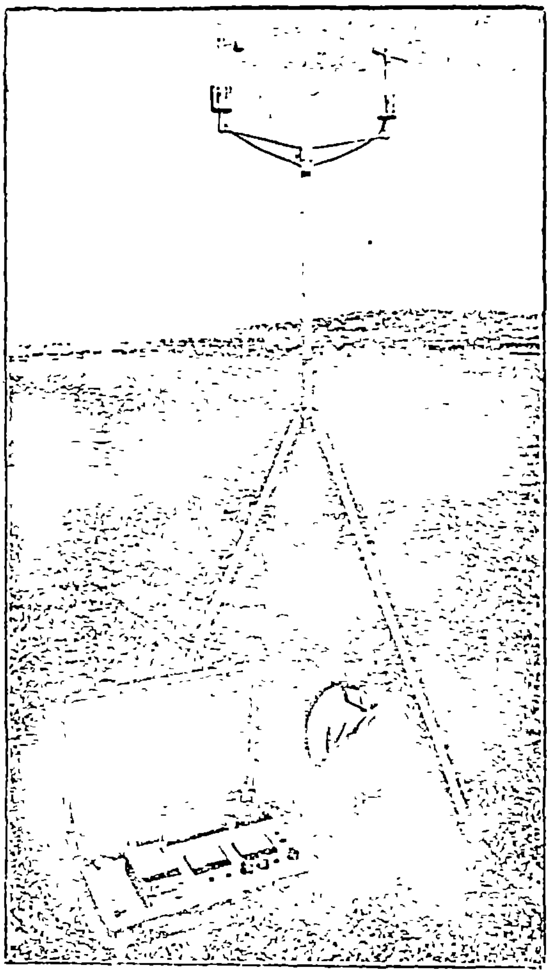
The measurements took place on the following days.

| Date : | | | Measurements : |
|---|---|---|---|
| Tuesday | 3 Aug. | 1982 | A1 A2 A3 A4 A5 |
| Wednesday | 4 Aug. | 1982 | A6 A7 A8 A9 |
| Thursday | 5 Aug. | 1982 | B1 B2 D1 B3 |
| Friday | 6 Aug. | 1982 | B6 B5 D2 B4 B8 D4 |
| Monday | 9 Aug. | 1982 | D3 C2 C1 C3 |
| Tuesday | 10 Aug. | 1982 | B7 B9 B10 B11 |
| Wednesday | 11 Aug. | 1982 | D5 B12 |

The weather conditions are constant during all days.
Clouds covering most of the sky, reasonable wind, no rain (during the measurements) and a temperature of 25 $C^{o} \pm 2$.
The measurements took place during day-time, starting from 9.30 hr.

List of equipment

1. Portable Anemograph; Vector Instruments type R500



Description: A fully portable equipment for indicating and recording wind speed and direction. Included are a Porton Anemometer, Porton Windvane, mounting arm with taper fittings, and a meter display and recording equipment built into a carrying case.
Wind speed and direction are displayed on two panel meters and the same values are also recorded on the two channels of a miniature strip chart recorder.
Three way filter switches are provided for selecting the required averaging period for display meter and recorder, and a calibration facility allows meter and recorder indications to be set to reference values before use and re-checked after a recording session.
The equipment is powered by a mains re-chargeable battery supply.

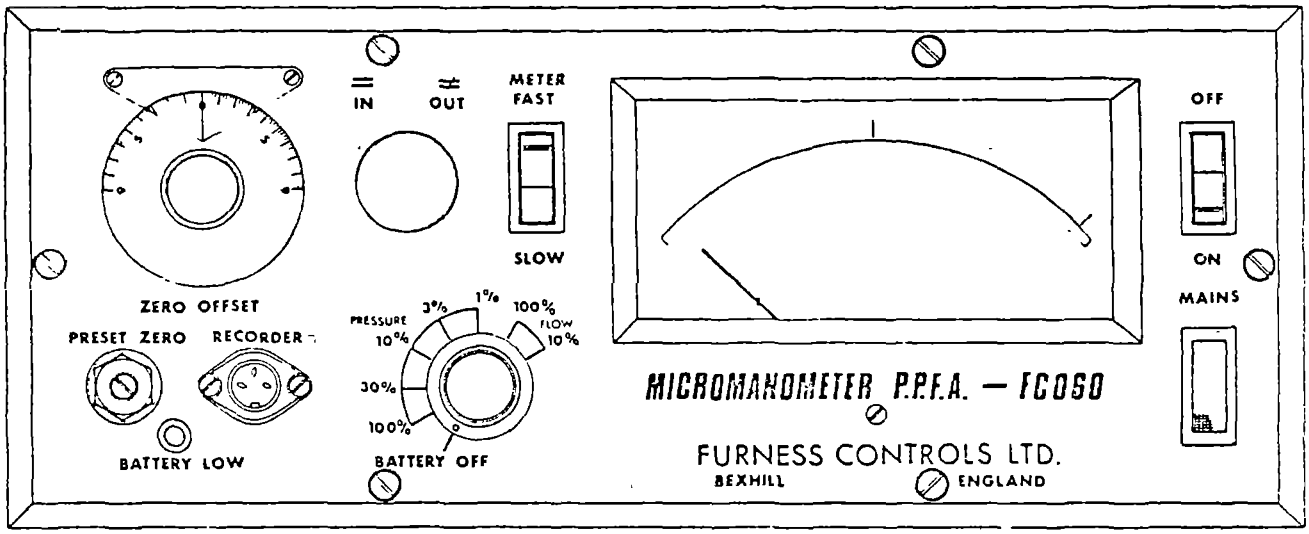
Accuracy: Speed: $\pm 2\frac{1}{2}\%$ ($\pm$0.25 m/s below 10 m/s)
Direction: $\pm 3\%$
Filter averaging times: Position 10: 10 sec. $\pm 20\%$
Chart speed: 3.0 inches/hour $\pm 2\%$
Range of measurement: Speed: Range 1: 0-10m/s in 0.2m/s divisions.
Direction: $600^{\circ}$ Scale in $10^{\circ}$ divisions.

2. Micromanometer; Furness Controls Ltd PPFA - FC060
Components: Measuring head -pitot-tube
Micromanometer -sensitive pressure measuring unit with a total range of 10,000 : 1 to an accuracy of 1% in any range.

Flow Ranges: 100% Flow = 9 m/s ≡ 5 mm $H_2O$
10% Flow = 0.9 m/s 0.05 mm $H_2O$

The fast-slow meter switch gives a time constant for turbulent flow (slow position gives 5 seconds)

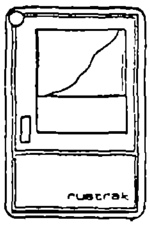
The equipment is powered by a mains re-chargeable battery supply.




3. Recorder; Rustrak 200, Gulton

The recorder is connected to the micromanometer. Calibration facility allows recorder indication to be set to reference value.

Chart speed: 6.0 inches/hour.




200

## The Distribution of $t$* (Two-tailed Tests)

| Degrees of Freedom | Probability of a Larger Value, Sign Ignored | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0.500 | 0.400 | 0.200 | 0.100 | 0.050 | 0.025 | 0.010 | 0.005 | 0.001 |
| 1 | 1.000 | 1.376 | 3.078 | 6.314 | 12.706 | 25.452 | 63.657 | | |
| 2 | 0.816 | 1.061 | 1.886 | 2.920 | 4.303 | 6.205 | 9.925 | 14.089 | 31.598 |
| 3 | .765 | 0.978 | 1.638 | 2.353 | 3.182 | 4.176 | 5.841 | 7.453 | 12.941 |
| 4 | .741 | .941 | 1.533 | 2.132 | 2.776 | 3.495 | 4.604 | 5.598 | 8.610 |
| 5 | .727 | .920 | 1.476 | 2.015 | 2.571 | 3.163 | 4.032 | 4.773 | 6.859 |
| 6 | .718 | .906 | 1.440 | 1.943 | 2.447 | 2.969 | 3.707 | 4.317 | 5.959 |
| 7 | .711 | .896 | 1.415 | 1.895 | 2.365 | 2.841 | 3.499 | 4.029 | 5.405 |
| 8 | .706 | .889 | 1.397 | 1.860 | 2.306 | 2.752 | 3.355 | 3.832 | 5.041 |
| 9 | .703 | .883 | 1.383 | 1.833 | 2.262 | 2.685 | 3.250 | 3.690 | 4.781 |
| 10 | .700 | .879 | 1.372 | 1.812 | 2.228 | 2.634 | 3.169 | 3.581 | 4.587 |
| 11 | .697 | .876 | 1.363 | 1.796 | 2.201 | 2.593 | 3.106 | 3.497 | 4.437 |
| 12 | .695 | .873 | 1.356 | 1.782 | 2.179 | 2.560 | 3.055 | 3.428 | 4.318 |
| 13 | .694 | .870 | 1.350 | 1.771 | 2.160 | 2.533 | 3.012 | 3.372 | 4.221 |
| 14 | .692 | .868 | 1.345 | 1.761 | 2.145 | 2.510 | 2.977 | 3.326 | 4.140 |
| 15 | .691 | .866 | 1.341 | 1.753 | 2.131 | 2.490 | 2.947 | 3.286 | 4.073 |
| 16 | .690 | .865 | 1.337 | 1.746 | 2.120 | 2.473 | 2.921 | 3.252 | 4.015 |
| 17 | .689 | .863 | 1.333 | 1.740 | 2.110 | 2.458 | 2.898 | 3.222 | 3.965 |
| 18 | .688 | .862 | 1.330 | 1.734 | 2.101 | 2.445 | 2.878 | 3.197 | 3.922 |
| 19 | .688 | .861 | 1.328 | 1.729 | 2.093 | 2.433 | 2.861 | 3.174 | 3.883 |
| 20 | .687 | .860 | 1.325 | 1.725 | 2.086 | 2.423 | 2.845 | 3.153 | 3.850 |
| 21 | .686 | .859 | 1.323 | 1.721 | 2.080 | 2.414 | 2.831 | 3.135 | 3.819 |
| 22 | .686 | .858 | 1.321 | 1.717 | 2.074 | 2.406 | 2.819 | 3.119 | 3.792 |
| 23 | .685 | .858 | 1.319 | 1.714 | 2.069 | 2.398 | 2.807 | 3.104 | 3.767 |
| 24 | .685 | .857 | 1.318 | 1.711 | 2.064 | 2.391 | 2.797 | 3.090 | 3.745 |
| 25 | .684 | .856 | 1.316 | 1.708 | 2.060 | 2.385 | 2.787 | 3.078 | 3.725 |
| 26 | .684 | .856 | 1.315 | 1.706 | 2.056 | 2.379 | 2.779 | 3.067 | 3.707 |
| 27 | .684 | .855 | 1.314 | 1.703 | 2.052 | 2.373 | 2.771 | 3.056 | 3.690 |
| 28 | .683 | .855 | 1.313 | 1.701 | 2.048 | 2.368 | 2.763 | 3.047 | 3.674 |
| 29 | .683 | .854 | 1.311 | 1.699 | 2.045 | 2.364 | 2.756 | 3.038 | 3.659 |
| 30 | .683 | .854 | 1.310 | 1.697 | 2.042 | 2.360 | 2.750 | 3.030 | 3.646 |
| 35 | .682 | .852 | 1.306 | 1.690 | 2.030 | 2.342 | 2.724 | 2.996 | 3.591 |
| 40 | .681 | .851 | 1.303 | 1.684 | 2.021 | 2.329 | 2.704 | 2.971 | 3.551 |
| 45 | .680 | .850 | 1.301 | 1.680 | 2.014 | 2.319 | 2.690 | 2.952 | 3.520 |
| 50 | .680 | .849 | 1.299 | 1.676 | 2.008 | 2.310 | 2.678 | 2.937 | 3.496 |
| 55 | .679 | .849 | 1.297 | 1.673 | 2.004 | 2.304 | 2.669 | 2.925 | 3.476 |
| 60 | .679 | .848 | 1.296 | 1.671 | 2.000 | 2.299 | 2.660 | 2.915 | 3.460 |
| 70 | .678 | .847 | 1.294 | 1.667 | 1.994 | 2.290 | 2.648 | 2.899 | 3.435 |
| 80 | .678 | .847 | 1.293 | 1.665 | 1.989 | 2.284 | 2.638 | 2.887 | 3.416 |
| 90 | .678 | .846 | 1.291 | 1.662 | 1.986 | 2.279 | 2.631 | 2.878 | 3.402 |
| 100 | .677 | .846 | 1.290 | 1.661 | 1.982 | 2.276 | 2.625 | 2.871 | 3.390 |
| 120 | .677 | .845 | 1.289 | 1.658 | 1.980 | 2.270 | 2.617 | 2.860 | 3.373 |
| $\infty$ | .6745 | .8416 | 1.2816 | 1.6448 | 1.9600 | 2.2414 | 2.5758 | 2.8070 | 3.2905 |

* Parts of this table are reprinted by permission from R. A. Fisher's *Statistical Methods for Research Workers*, published by Oliver and Boyd, Edinburgh (1925–1950); from Maxine Merrington's "Table of Percentage Points of the $t$-Distribution," Biometrika, 32: 300 (1942); and from Bernard Ostle's *Statistics in Research*, Iowa State University Press (1954).