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Pit Latrine Ventilation: Field Investigation Methodology

by Beverley Ryan and D. Duncan Mara

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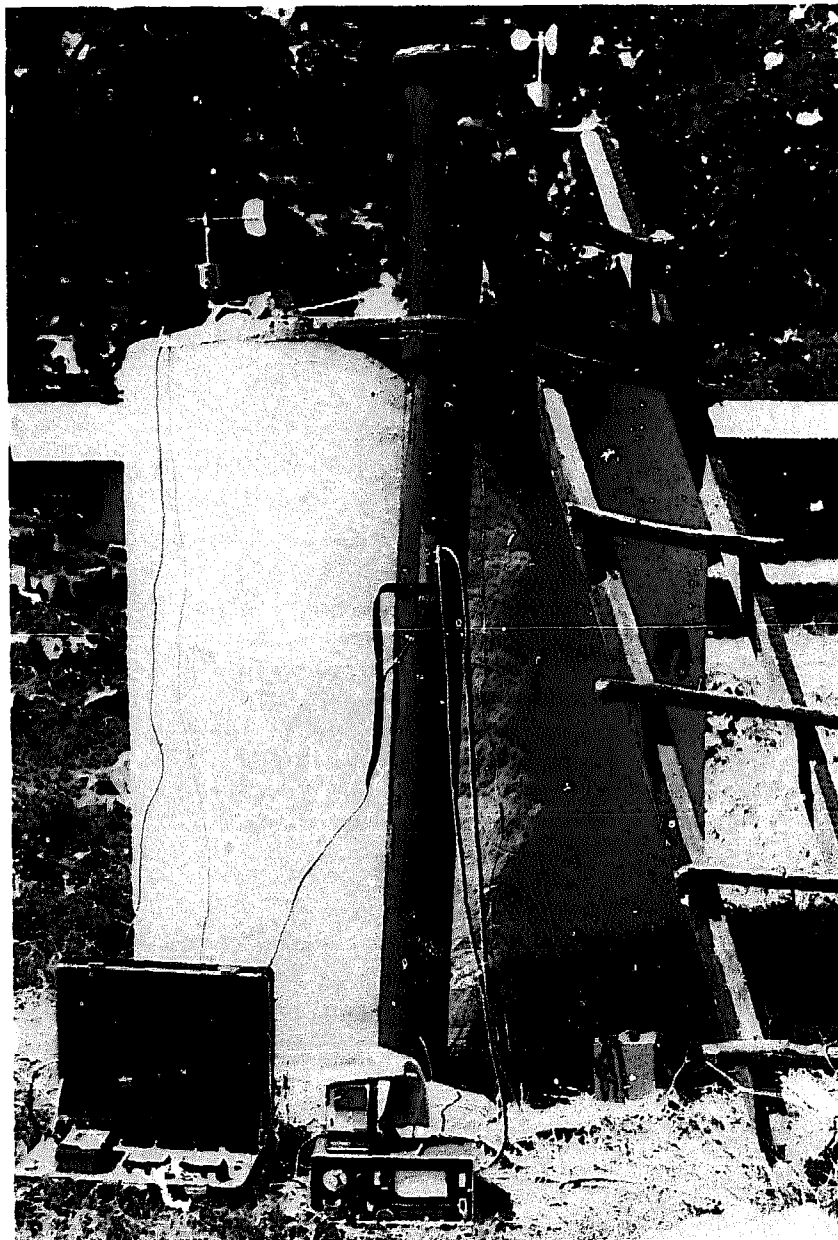
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TAG Technical Note No. 4

**United Nations Development Programme
Interregional Project INT/81/047
Executing Agency: World Bank**

Pit Latrine Ventilation: Field Investigation Methodology

**by Beverley A. Ryan (Consultant) and
D. Duncan Mara, Technical Advisory Group (TAG)**



**A joint United Nations Development Programme
and World Bank Contribution to the International
Drinking Water Supply and Sanitation Decade**

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PREFACE

"Pit Latrine Ventilation: Field Investigation Methodology" by Beverley A. Ryan and D. Duncan Mara describes a suggested methodology for field investigations into the ventilation performance of ventilated improved pit latrines, based on fieldwork done in Botswana and Zimbabwe.

This paper is one of a series of informal Technical Notes prepared by TAG^{1/} on various aspects of water supply and sanitation programs in developing countries. The papers were originally prepared as internal discussion documents; their wider distribution does not imply endorsement by the sector agencies, government, or donor agencies concerned with the programs, nor by the World Bank or the United Nations Development Programme. Comments and suggestions on the papers should be addressed to the Project Manager, UNDP Project INT/81/047, Water Supply and Urban Department, The World Bank, 1818 H Street, NW, Washington, DC, 20433.

Richard N. Middleton
Project Manager

^{1/} TAG: Technology Advisory Group established under the United Nations Development Programme Global Project GLO/78/006 (renumbered on January 1, 1982; now UNDP Interregional Project INT/81/047: "Development and Implementation of Low-cost Sanitation Investment Projects"), executed by the World Bank.

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SUMMARY

This Technical Note describes a suitable methodology for the investigation in the field of the ventilation performance of ventilated improved pit (VIP) latrines, based on fieldwork done in Botswana and Zimbabwe. The methodology is based on monitoring the temperature environment of the latrine, the velocity of air flow within the vent pipe, the wind speed across the top of the vent pipe and the variation of atmospheric pressure inside and outside the latrine. With this information it is possible to determine whether, in any given location, the ventilation is caused primarily by the absorption of solar energy by the vent pipe or by the shear effect of the wind across the top of the vent pipe. The fieldwork done in Botswana and Zimbabwe indicated that the latter mechanism was generally the more important, but under low wind conditions this may not be true so that there is always a need for field investigations prior to the large-scale installation of VIP latrines.

**PIT LATRINE VENTILATION
FIELD INVESTIGATION METHODOLOGY**

INTRODUCTION

1. Research by the World Bank^{1/} has identified the ventilated improved pit (VIP) latrine as offering most of the health and convenience benefits of conventional waterborne waste disposal at a small fraction of its cost. There are various designs of VIP latrines (Figure 1) but they all differ from conventional pit latrines in having a vent pipe, which generates an updraft and so maintains a flow of air down through the squatting plate. The effect of this air current is to minimize odors and to discourage fly breeding within the pit; moreover, if the exit of the vent pipe is covered with a mesh and if the latrine superstructure is kept reasonably dark, any flies which do hatch out in the pit will be attracted to the daylight at the top of the pipe, where they will be trapped by the mesh and eventually die.^{2/}

2. The VIP latrine (and its variant with alternating twin pits) is probably the most appropriate technology for a wide variety of conditions in low-income urban and rural communities in many developing countries. However, systematic application of the principles of the VIP latrine has so far been limited to a few countries, notably Zimbabwe^{3/}, Botswana, Ghana Lesotho and Tanzania.

VENTILATION MECHANISMS

3. In order to be able to design the vent pipe optimally, and hence minimize costs, it is necessary to have an understanding of the physical mechanisms responsible for inducing and maintaining the circulation of air through the latrine system. There are two possible mechanisms for this:

- (a) the thermal effect of solar radiation on the vent pipe's external surface; and
- (b) the suction effect of wind across the top of the vent pipe.

^{1/} J. M. Kalbermatten, D. S. Julius and C. G. Gunnerson, "Appropriate Sanitation Alternatives: A Technical and Economic Appraisal", World Bank Studies in Water Supply and Sanitation, 1, The Johns Hopkins University Press, Baltimore and London, (1982).

^{2/} P. R. Morgan, "The Pit Latrine - Revived", Central African Journal of Medicine, 23, 1-7 (1977).

^{3/} Peter R. Morgan and D. Duncan Mara, "Ventilated Improved Pit Latrines: Recent Developments in Zimbabwe", World Bank Technical Paper Number 3, The World Bank, Washington, DC (1982).

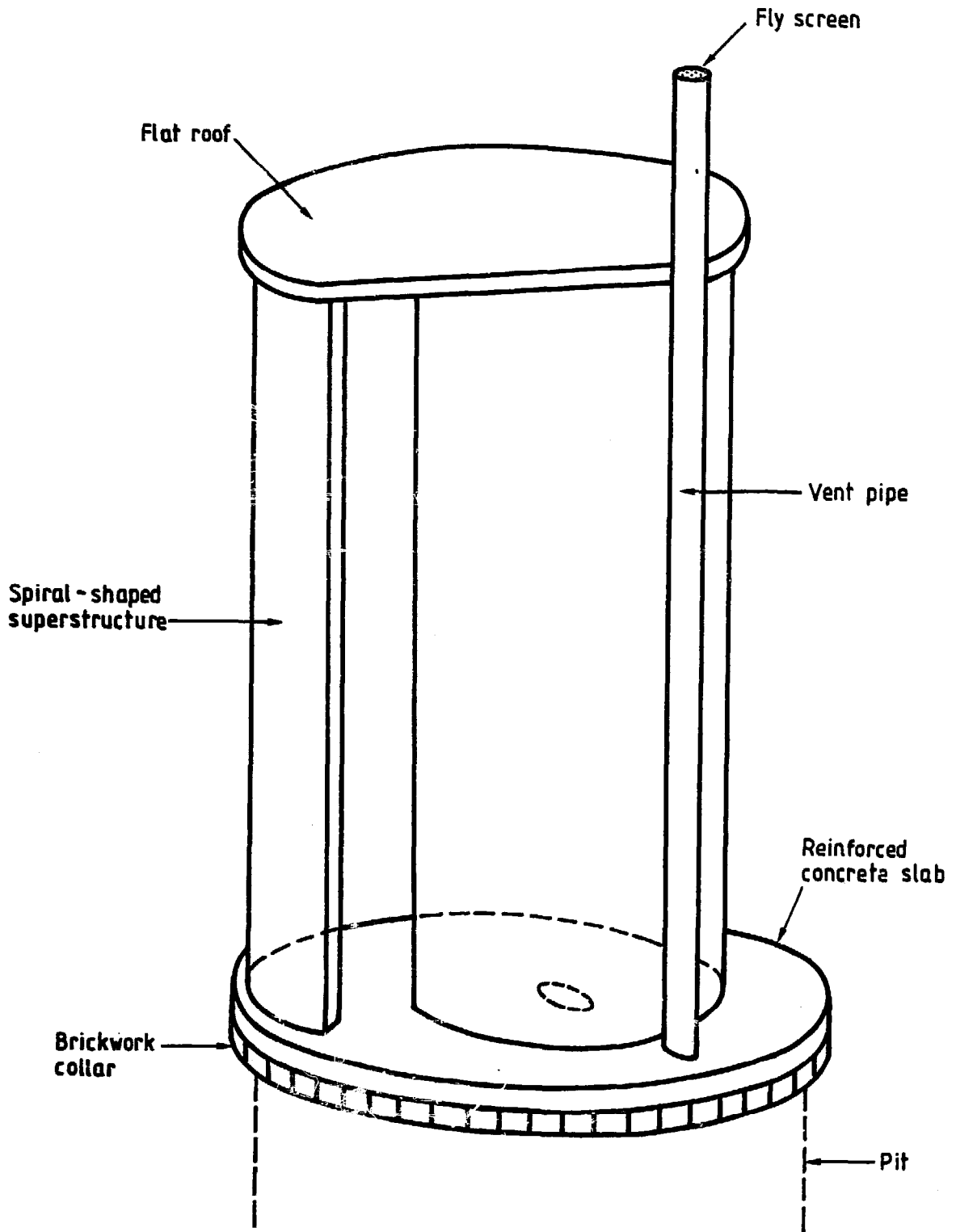


Figure 1 (a). Zimbabwean spiral VIP latrine.

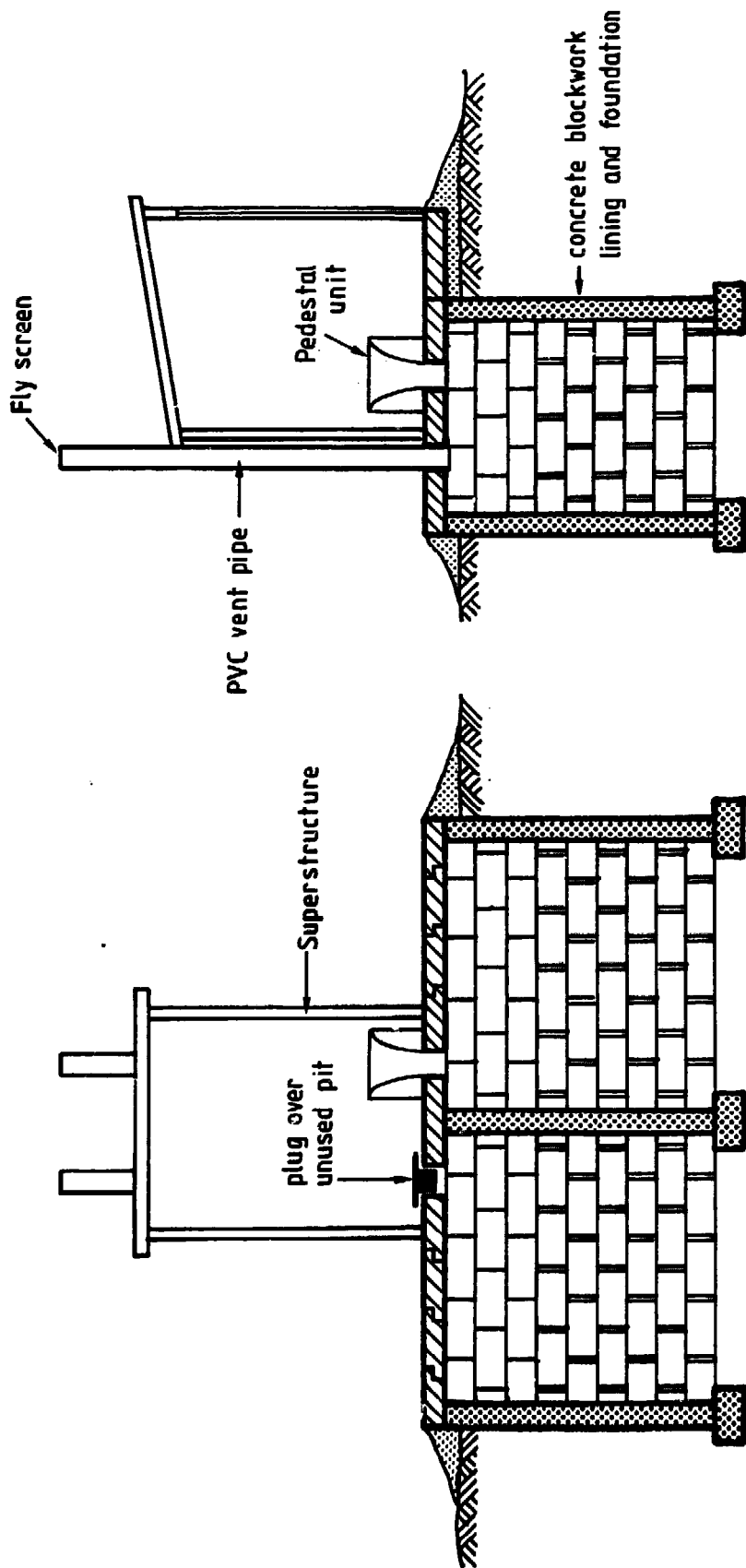


Figure 1 (b). Botswanan alternating twin pit VIP latrine.

4. **Solar radiation.** The effect of solar radiation is to heat up the vent pipe and thus the air inside it. This air becomes less dense and therefore rises up the vent pipe, and is replaced by cooler air from below. In this way a circulation of air is created through the superstructure and pit and thence up the vent pipe. Any odors emanating from the fecal material in the pit are thus drawn up the vent pipe, so leaving the superstructure odor-free.

5. **Wind.** The effect of wind passing across the top of the vent pipe is to create a suction within the pipe, so that air is drawn out and replaced by air from below, thus establishing the air circulation pattern described above.^{4/}

6. Recently studies were done in Botswana and Zimbabwe, funded by the United Nations Development Programme Interregional Project INT/81/047 and the British Science and Engineering Research Council^{5/}, to determine the relative importance of these two mechanisms. These studies showed that wind speed and direction are the primary factors causing ventilation of the pit; thermally induced updraught is of relatively minor importance. As a consequence of this, 200 mm diameter vent pipes were found to be considerably more effective than 150 or 100 mm diameter pipes. Blackening the external surface of the vent pipe (to increase the absorption of solar radiation) had only a very small effect on increasing the venting velocity, but this factor maybe of greater importance under "no wind" conditions. The direction of the wind relative to openings (doors, windows) in the superstructure was found to have a major influence on the ventilation efficiency. If the opening faces into the wind, the venting velocity increases substantially, due to the increased air pressure at the bottom of the vent pipe; if the opening does not face into the wind, there is little or no increase in air pressure and the principal mechanism causing ventilation is the "wind shear" effect across the top of the vent pipe. Recommendations for vent pipe design, based on current knowledge, are given in a separate Technical Note in this series^{6/}.

7. From these African studies it has been possible to identify those design parameters which require further field investigation in areas where VIP latrines are to be adopted as the major component in low-cost sanitation programs, and where, therefore, optimization of vent pipe design is critical for cost minimization. These parameters are listed in paragraph 11.

4/ R.F. Carroll, "Sanitation for Developing Countries", Overseas Building Note No. 189, Building Research Establishment, Garston, England (1982).

5/ B. A. Ryan, D. D. Mara and J. A. Fox, "Ventilation Mechanisms in Ventilated Improved Pit Latrines", Research Report Series, Department of Civil Engineering, University of Leeds, England (forthcoming).

6/ B. A. Ryan, D. D. Mara and G. H. Read, "Ventilated Improved Pit Latrines: Vent Pipe Design Guidelines", TAG Technical Note No. 6, The World Bank, Washington, DC (1983).

OBJECTIVES

8. The objectives of field investigations into vent pipe performance should normally be:

- (a) To determine the effects of wind speed, wind direction and solar radiation on the ventilation performance.
- (b) To determine the optimum position, diameter and height of the vent pipe. This should include investigations into the differences between the vent pipe being located inside and outside the superstructure.
- (c) To evaluate the minimum air flow required to reduce odor in the superstructure to below (i) the level perceived as a nuisance, and (ii) the threshold concentration for attracting insects.
- (d) To determine optimum designs for the fly screen at the top of the vent pipe and for the squat hole mosquito trap which may be necessary in high ground-water table areas.^{7/} Fly screens and mosquito traps cause substantial head losses and thus impede the air flow; it is therefore essential to determine the minimum air flow required for odor control when the fly screen and mosquito trap, if used, are in place.^{8/}
- (e) To combine these field results with previous theoretical studies (extended if necessary) to develop practical design tools for field workers.

INVESTIGATION PROCEDURES

9. In any country the latrines selected for investigation should so far as possible represent the full range of latrine designs and installation conditions found there; at least two of each of the principal types of ventilated latrines should be included.

10. In order to evaluate diurnal and seasonal variations in vent pipe performance, each latrine should be monitored over a twenty-four hour period at least once, preferably twice, each month for twelve months.

^{7/} C. F. Curtis, "Mosquito traps for pit latrines", Mosquito News, 40, 626-628 (1980).

^{8/} Fly screens require regular inspection and cleaning by the householder; optimization of vent pipe height should take this simple maintenance requirement into account.

11. Monitoring should normally cover the following parameters:

(a) Temperature

Temperature measurements (with an accuracy to within plus or minus 0.1 degrees Celsius) should be taken of:

- (i) the air inside the vent pipe (top and bottom);
- (ii) the surface of the vent pipe;
- (iii) the ambient (shade) air temperature;
- (iv) the inside of the latrine superstructure; and
- (v) the air in the free space within the pit.

Wet and dry bulb ambient shade temperatures should also be measured (using a whirling hygrometer) to determine relative humidity.

(b) Wind velocity

Local wind speed and direction should be measured at a point which is as near as possible to, and at the same height as, the top of the vent pipe.

(c) Venting velocity

The air velocity and direction within the vent pipe should be measured centrally within the pipe at the mid-point of its overall length.

(d) Odor

Odor levels within the latrine superstructure and in adjacent areas likely to affect neighboring properties (arbitrarily defined as within a ten meter radius^{9/}) should be determined using the latrine users' perception, as follows:

- 0. No odor.
- 1. Inoffensive odor.
- 2. Offensive odor.
- 3. Highly offensive odor.

^{9/} On the results sheet (Annex II) these are shown as recorded 10 meters upstream and downstream of the latrine. Site-specific modifications should be carefully noted on the sheets.

(e) Air pressure

The air pressure should be measured at the top and bottom of the vent pipe, near the squat hole, and at the latrine entrance.

12. Each of these measurements should be monitored continuously throughout the twenty-four hour period. The equipment required for these measurements is shown in Figure 2 and described in detail in Annex I. Typical temperature probe locations and air pressure measurement points are shown in Figure 3.

13. For each day during which monitoring is carried out, the following should also be recorded:

- (a) average solar radiation intensity ($\text{cal}/\text{cm}^2/\text{day}$); the instrument used for this purpose should be reported;
- (b) number of sunshine hours (determined by a Campbell Stokes tropical sunshine recorder);
- (c) maximum and minimum daily temperature (degrees Celsius);
- (d) rainfall/open pan evaporation (mm);
- (e) average atmospheric pressure (N/m^2);
- (f) relative humidity (%).

If this information is obtained from a local meteorological station, the location and distance of this station from each latrine should be reported.

14. A suggested format for entering the results is given in Annex 2. It is usually helpful to have a photograph as well as an engineering drawing of each latrine, showing the location of the latrine relative to nearby houses, trees, etc., and indicating magnetic North. Full details of the vent pipe (material, internal and external diameters, surface treatment, total and heated lengths, fly screen details) should be obtained. Sectional and other details (to illustrate, for example, the arrangement of the vent pipe, its exposure to the sun, structural or vegetative shade, ventilation provisions in the superstructure door or walls and latrine cover slab, position of the groundwater table) will also be needed so that the results obtained can be properly interpreted and correlated with those from other sites. Semi-quantitative estimates of fly and mosquito nuisance, if any, should also be made. The presence or absence of a squat-hole mosquito trap should be noted; if one is in use, it should be fully described. The year in which the latrine was built, the number of people using it and how full its pit is, should also be determined.

15. A sample of the fly screen material used (at least 150 mm x 150 mm) should be obtained in order to determine its air flow head-loss coefficient and to evaluate it as an insect barrier.

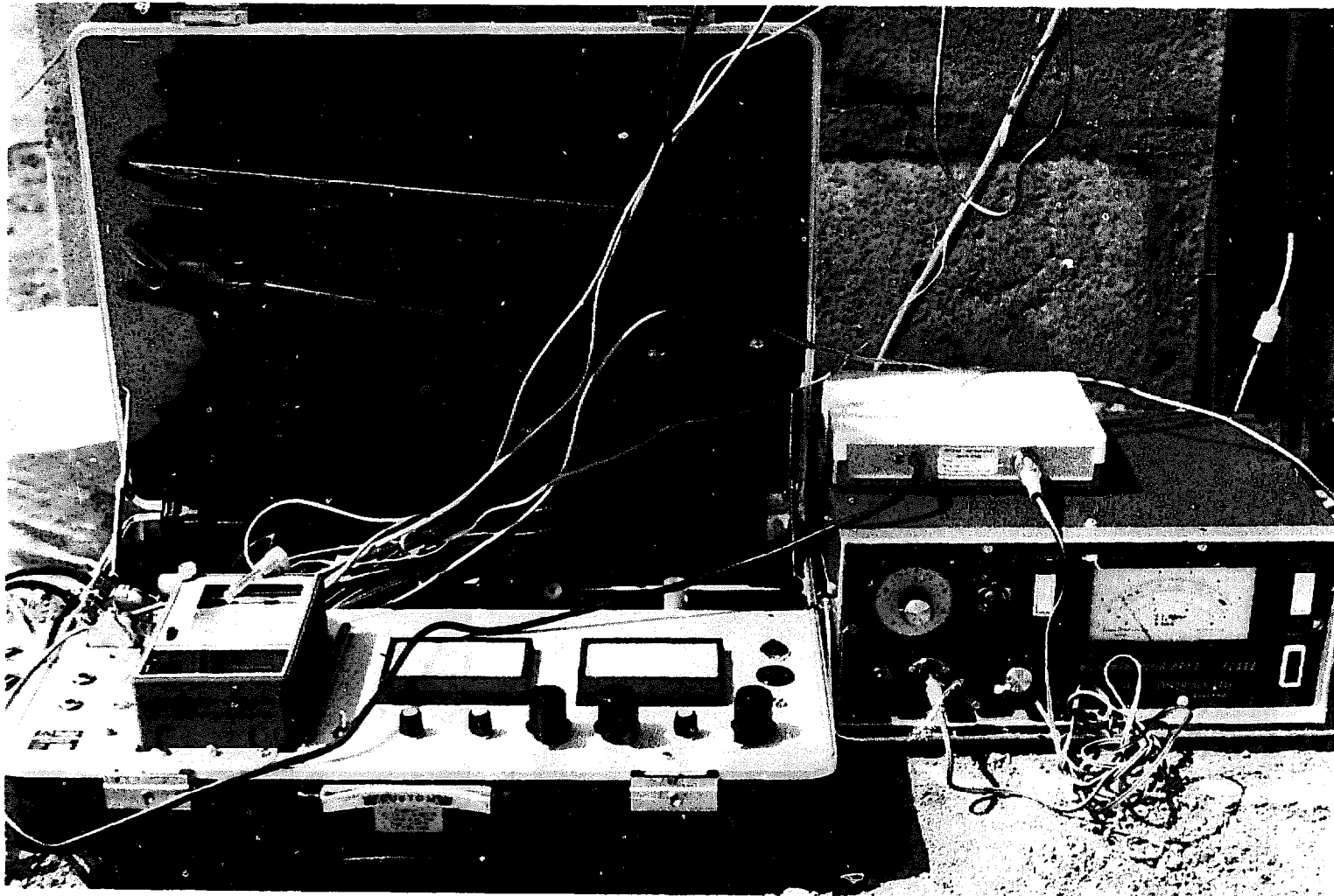


Figure 2 (a). Equipment used to monitor ventilation performance of VIP latrines.

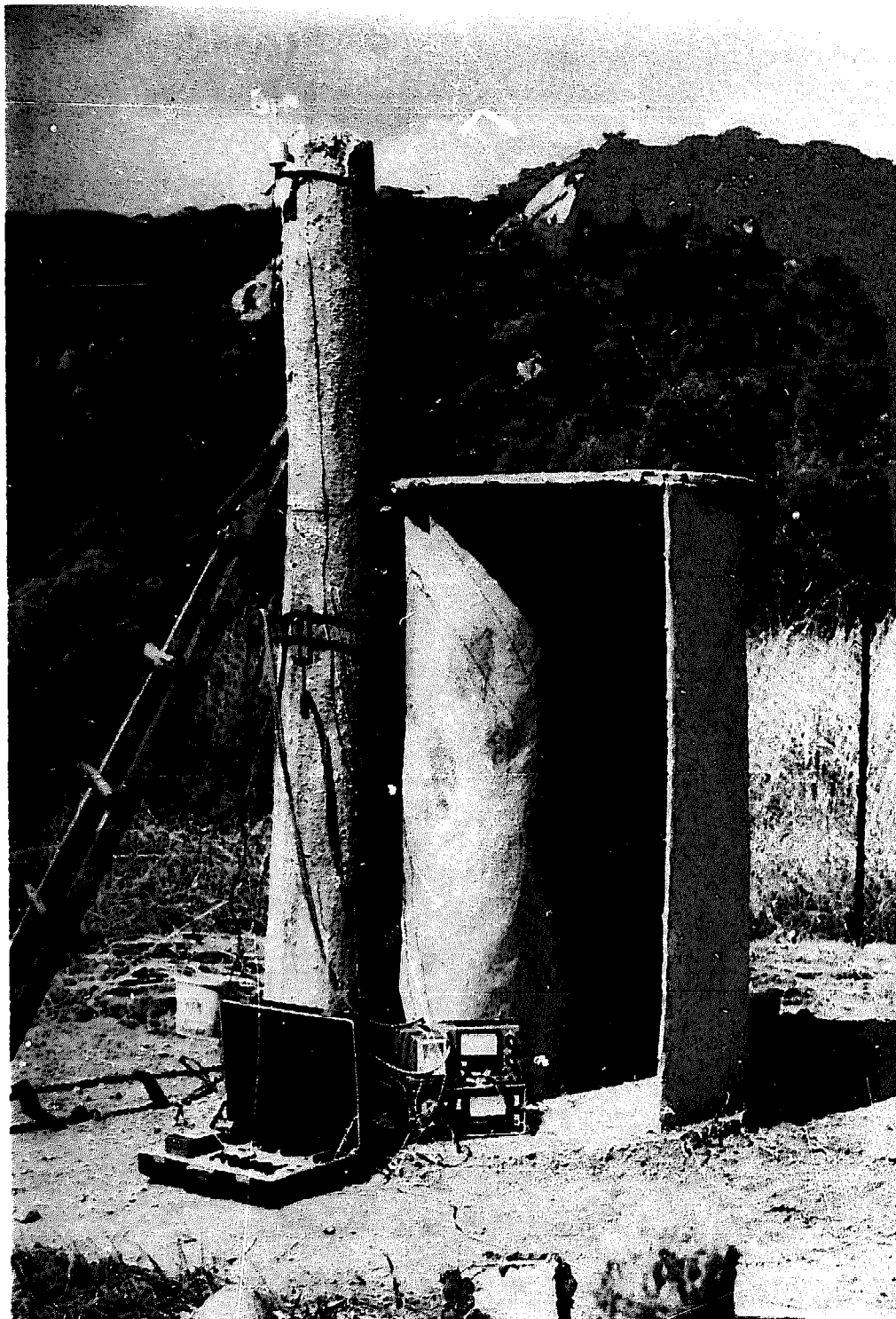


Figure 2 (b). Field set-up of equipment used to monitor ventilation performance of VIP latrines.

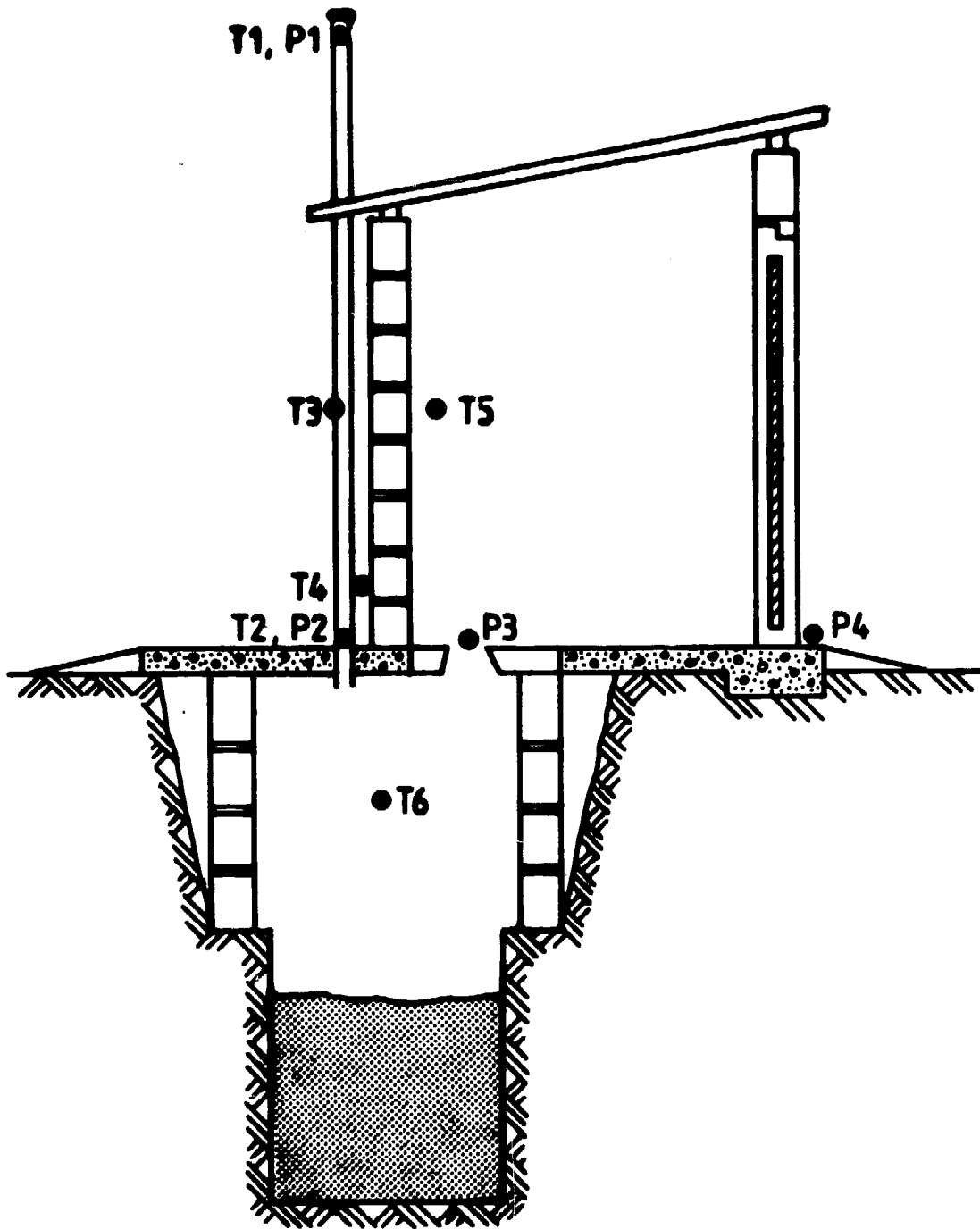


Figure 3. Location of temperature probes T1 through T6 and air pressure measurement points P1 through P4.

16. The Interregional Project would be interested in hearing from any investigators who have done, or are planning to do, ventilation monitoring as described in this Note. The Project will advise on equipment, procedures and interpretation of results, and will assist in disseminating findings. Correspondence should be addressed to the Project Manager (see Preface).

EQUIPMENT NEEDED FOR VIP VENTILATION STUDIES

An air velocity meter, temperature monitoring equipment and an anemometer will normally be the only instruments needed on site. These are briefly discussed below^{1/}.

1. Air velocity meter. The meter should be able to measure vent pipe air velocities in the range 0.01 - 5 m/s. In practice this limits the choice of equipment to a hot-wire anemometer (e.g., Wallac thermo-anemometer model GGA23S with model NH 125-ANE velocity probe^{2/}) or a pitot tube used with a micromanometer (e.g., Furness Controls model 1 portable pressure and flow analyser with model 600 bent shaft pitot tube^{3/}). The pitot tube and micromanometer are more useful as they can be used to determine the air pressure distribution within the latrine and its immediate vicinity.
2. Temperature monitoring equipment. The most convenient equipment comprises a multi-channel Wheatstone bridge temperature meter and thermistor probes; for example, the YSI model 44 21 channel telethermometer (temperature range: 15 - 100°C^{4/}) in conjunction with YSI model 401 general purpose thermistor probes (for probe locations T1, T2, T4, and T6 shown in Figure 2) and a model 490B attachable surface probe (for location T3). Probe extension leads (e.g., the model 4010 3 m extension lead) will normally be useful. A whirling hygrometer is also required to determine the relative humidity.
3. Anemometer. A variety of equipment is available; probably the most suitable is a unit which measures both wind speed and direction, such as the Vector model R500 portable anemograph^{5/}, which includes an anemometer, windvane, dual mounting arm and an indicator/recording unit. The length of cable which connects the anemometer and windvane to the indicator/recording unit should be 4 meters.

All of the above mentioned items are battery-operated and have facilities for connection to a chart recorder or a data logger (both these items should also be battery-operated). Connection to both a chart recorder and a data logger (with connection to the latter via the former) is ideal, as

^{1/} Mention of any particular commercially available item of equipment is made only to indicate the type of equipment which would be suitable for this application. It should not be interpreted as in any way implying an exclusive recommendation for it by the UNDP Interregional Project INT/81/047.

^{2/} Wallac Oy, PO Box 10, 20101 Turku 10, Finland.

^{3/} Furness Controls Ltd., Beeching Road South, Bexhill-on-Sea TN39 3LJ, United Kingdom.

^{4/} Yellow Springs Instruments Co., Yellow Springs, Ohio 45387, U.S.A.

^{5/} Vector Instruments, 113 Marsh Road, Rhyll LL18 2AB, United Kingdom.

the data is recorded both graphically (for visual inspection) and digitally (for ease of subsequent computer analysis). A suitable battery operated data logger is the Campbell model CR61 Micrologger^{6/}, which may be used in conjunction with a Mass Storage Unit^{7/}, for additional data storage capacity. Data recording in graphical and digital form is of importance in fundamental studies (for example, to correlate vent pipe flow peaks with wind speed peaks or changes in wind direction), but is of less importance in routine monitoring of vent pipe performance.

It will generally be helpful to have available the following additional items:

- (1) a clamp for the anemometer (so that it can be attached to the top of the vent pipe);
- (2) a holder and straps for the pitot tube;
- (3) thick-walled tubing for the pitot tube;
- (4) draughting tape (to hold the temperature probes in position);
- (5) a hand drill and various drill bits, in order to drill holes into the vent pipe to accommodate the pitot tube and temperature probes;
- (6) a ladder;
- (7) spare batteries for the monitoring instrument; and
- (8) a weatherproof container in which to store all the equipment.

^{6/} Campbell Scientific, Inc., PO Box 551, Logan, Utah 84321, U.S.A.

^{7/} Abacus Microproducts, Index House, Ascot, Berkshire SL5 7EV, United Kingdom.

RESULTS SHEET

Attached to this Annex are two pages which give the suggested format for entering the results. If the results are to be sent to the UNDP Interregional Project for analysis, the following points on format are important as the results will be analyzed by computer. Data which are being recorded continuously need not, of course, be entered on the results sheet.

- (a) Latrine code: use the first two letters of the country followed by 01, 02, etc., e.g. TA01 for latrine reference number 1 in Tanzania.
- (b) Date: follow American practice - month, day, year, using an initial zero for days and months 1 through 9, e.g., March 9, 1981, would be 03/09/81.
- (c) Data recorded by: use three initials only.
- (d) Time: use the 24-hour clock.
- (e) Venting velocity and direction: record as positive (+) for air going up the vent, negative (-) for down the vent. Record velocity in meters/second (m/s) to two decimal places only.
- (f) Air pressure: P1 through P4 refer to the air pressure measurement points in Figure 2. Record air pressure to nearest mm Hg.
- (g) Wind velocity: record to nearest 0.1 m/s.
- (h) Wind direction: record direction from which wind is coming as wind angle (0 - 360°), or else as N, NE, E, SE, S, SW, W, NW only.
- (i) Odor: record householder's perception on the scale 0 - 3 as indicated in paragraph 11(d) above.
- (j) Temperature: T1 through T6 refer to temperature probe location points shown in Figure 2 and listed in paragraph 11(a) above. Record temperature to one decimal place only.
- (k) Relative humidity: calculate from wet and dry bulb temperatures using the chart provided with the whirling hygrometer. Record to nearest one percent.

UNDP INTERREGIONAL PROJECT INT/81/047 - FIELD EXPERIMENTS ON VIP LATRINE VENTILATION - RESULTS SHEET

Country: _____ Latrine code: _____ Date: _____ Data recorded by: _____

TIME	Venting velocity (m/s) and direction	Air Pressure (mm Hg)				Wind Velocity (m/s)	Wind Direction	Odor (0 - 3)			Temperature (°C)						Relative Humidity %	
		P1	P2	P3	P4			I	U	D	T1	T2	T3	T4	T5	T6		

NOTE: For locations of P, T measurements see Figure 3. Odor is measured inside the latrine (I) and 10 meters upwind (U) and downwind (D).

Meteorological data

Solar radiation intensity: _____ cal/cm²/day

No. of sunshine hours: _____

Maximum temperature _____ °C

Minimum temperature: _____ °C

Rainfall: _____ mm

Evaporation: _____ mm

Relative humidity: _____ %

Description of weather
(e.g., extent of cloud cover, rainstorms, etc.)

Squat hole mosquito trap present? YES/NO

Other remarks:
(e.g., fly/mosquito/cockroach nuisance)