PAPER 12

CONTINUOUS MEASUREMENTS OF AIR INFILTRATION IN OCCUPIED DWELLINGS

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Continuous measurements of air infiltration in occupied buildings

The measurement system, developed by the Institute of Technology at Tåstrup, Denmark, is a microcomputer-controlled system for registering air change rates using tracer gas according to the constant concentration method.

The system is designed for measuring and metering tracer gas in up to ten separate rooms. The air change rate to outdoors is measured on the basis of the amount of tracer gas supplied to maintain a constant concentration.

The system operates through automatic data logging on a floppy disc and can run without supervision for extended periods (up to six days).

Background

In conjunction with energy saving measures, both in existing buildings and in new buildings, there is a natural desire to build as airtight as possible.

There has been a considerable amount of measurement of natural ventilation in buildings in Sweden and Denmark but such measurement has been of instantaneous values where outside doors, windows etc have been closed. This does not give any indication of the air change rate when the building is occupied, ie when the occupants open and close windows, go in and out of the building etc.

The prerequisite for being able to measure a building's airtightness in relation to

a: the building's air change rate when occupied

b: the building's content of gases and allergens

c: the building's energy consumption

is being able to measure the true air change rate over an extended period (1-2 weeks) while the building is occupied.

As an example, one could expect that the reason for the differences in formaldehyde concentration in the air and air change rates in Swedish and Danish investigations could be attributed to air change rates not being measured while the building is occupied.

Correspondingly, it can be shown that by making the building tighter, the frequency of the occupants opening windows etc increases so that the effective air change rate is greater than that demanded by the tightness. Thus there is a real risk of increasing the air change rate instead of reducing it.

Design of the system

The measurement system comprises a central unit in which the dosage, control and measurement units are housed (see figure 1).

From the central unit, 2 hoses go to each of the measurement rooms. One hose is used for dosing the gas while the other is used for collecting room air for central concentration control.

The dosing unit:

The dosing unit comprises a bottle of tracer gas (N_2O), 10 solenoid valves, 10 metering jets and a pressure gauge.

The dosage to individual rooms is determined by two parameters:

1. The pressure in the jet.

2. The opening period of the solenoid valve.

To be able to calculate the flow through the jet simply and satisfactorily, the pressure and the jet size are selected so that there is an over-critical flow in the jet's smallest cross section - "the mill". At an over-critical flow, the maximum possible velocity in the mill is the speed of sound.

Over-critical flow is achieved when the ratio between the available pressure and the exit pressure at the jet exceeds approximately 1.9.

When increasing the available pressure in excess of this ratio of 1.9, the mass flow is proportional to the available pressure and independent of the exit pressure.

In other words, when there is over-critical flow in the jet, the mass flow varies linearly with the pressure at the input side (the pressure used is in the region of 3 bar).

The room is dosed every 30 seconds. The dosage time can vary between 0 and 30 seconds but is set so that the minimum dosage is 2 seconds.

The jets used (see figure 3) have a very fine quadratic characteristic. 10 x 2 second doses provide the same amount of gas as 1 x 20 second dose.

The measurement unit:

The measurement unit comprises 10 3-way solenoid valves, a Uras 7 n infrared gas absorption detector and a gas suction pump.

The concentration of N_2O in the room air is measured with the aid of a two beam infrared gas absorption detector (see figure 6), and the measurements are expressed as the difference between the absorption of light in the two beams. The reference cell contains nitrogen, which does not absorb light in the measurement range of the detector. The measurement cell contains the gas to be measured.

A single measurement takes 30 seconds. Thus if 10 rooms are connected, the tracer gas measurement in the rooms can be determined every sixth minute.

There are two components in the room air in addition to N_2O that absorb light in the detector's measurement range. The effect of CO_2 is removed by inserting a filter in Uras and the effect of moisture in the air is eliminated mathematically.

In order to get "fresh air" in the measurement apparatus a pump is installed which pumps from the hoses not used in the measurement process.

To eliminate drift at the 0 point, a test gas with a 50 ppm N_2O concentration in N_2 is measured at fixed intervals. The measurement apparatus's O drift point is corrected mathematically.

Control and registration unit:

A microcomputer is used as a control and registration unit (SORD MARK II).

Results

The results of one day's measurements in a house are shown in figures 4 and 5.

The house is of a timber construction on two floors located in Køge.

Measurements were taken in all rooms while in use.

Room number	Description	Volume	Window open	Mixing fans
1	Living room	$84m^3$	No	Yes
2	Kitchen	$22m^3$	No	Yes
3	Hall	$9m^3$	No	No
4	Bathroom	$9m^3$	No	No
5	Stairwell	$32m^3$	Yes	Yes
6	Bedroom	$25m^3$	Yes	Yes?
7	Room	$38m^3$	No	Yes
8	WC	$7m^3$	To 3	No

The greatest problem encountered during measurement is maintaining a constant concentration of N_2O in rooms.

Different conditions limit the extent to which the concentration can be regulated:

1. The facility for mixing air in the room. For example, in bedrooms it is not possible to use mixing fans for mixing the room air at night.

2. The rooms are measured at fixed intervals of up to 6 minutes. If a window or door is opened, a certain time elapses before this is registered.

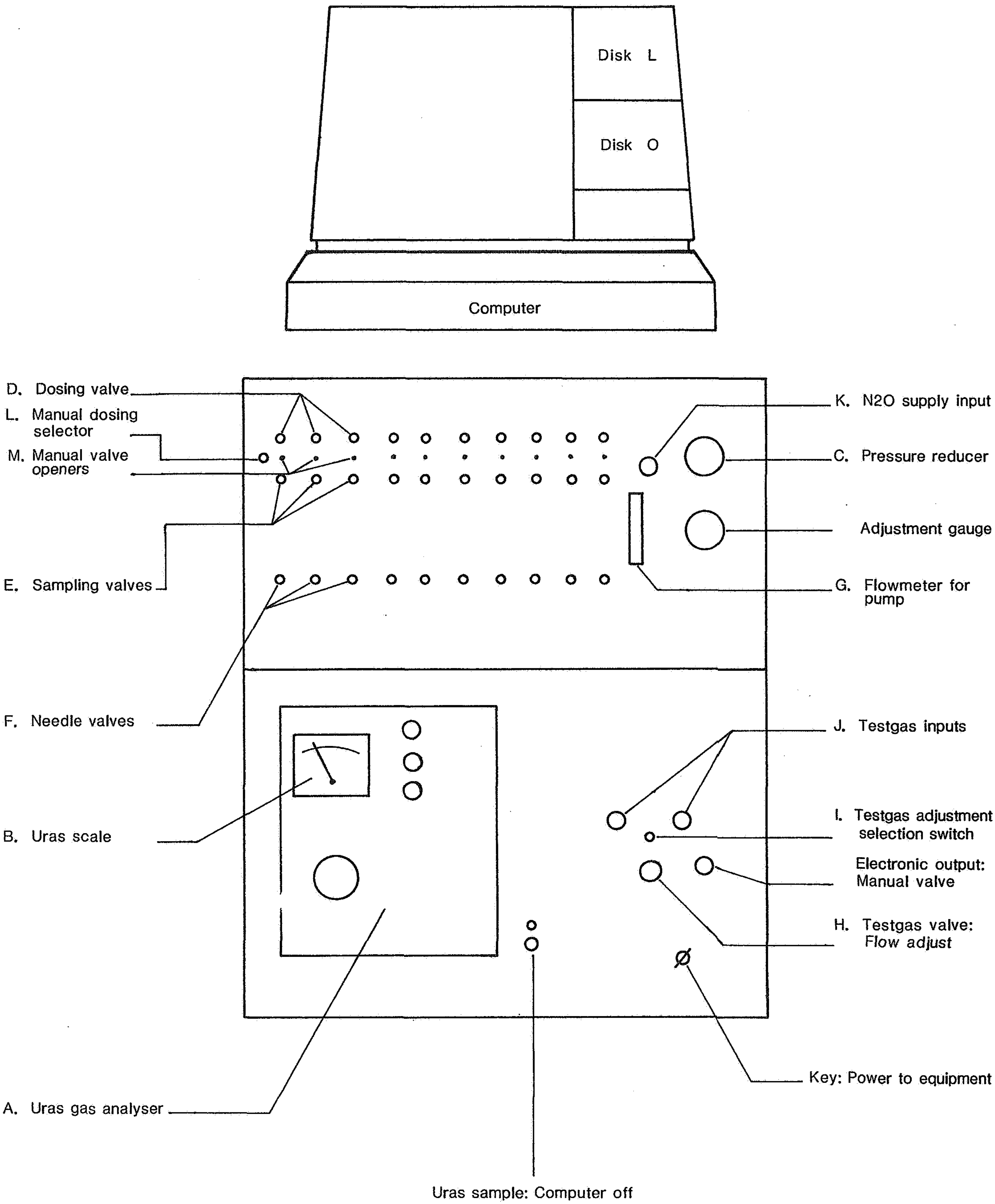
   The discontinuation of strong ventilation can result in an extended period of increased concentration in a room.

Figure 2 shows the result of a trial using two different types of control. The momentary concentration of N_2O was measured every minute.

Further development of the measurement system

Futher endeavours to improve the system will be to register temperature and moisture content in parallel with air change rate measurement. This will provide a better illustration of the indoor climate and will permit continual monitoring and correction of the effect of moisture on the URAS 7n.

We also hope to improve the dosage procedure so that even small rooms with a considerable air change rate can maintain a stable concentration of N_2O.



Disk L
Disk O
Computer
D. Dosing valve
L. Manual dosing selector
M. Manual valve openers
E. Sampling valves
F. Needle valves
B. Uras scale
A. Uras gas analyser
K. N2O supply input
C. Pressure reducer
Adjustment gauge
G. Flowmeter for pump
J. Testgas inputs
I. Testgas adjustment selection switch
Electronic output: Manual valve
H. Testgas valve: Flow adjust
Key: Power to equipment
Uras sample: Computer off

FIGURE 1

Design of the measurement apparatus, principle

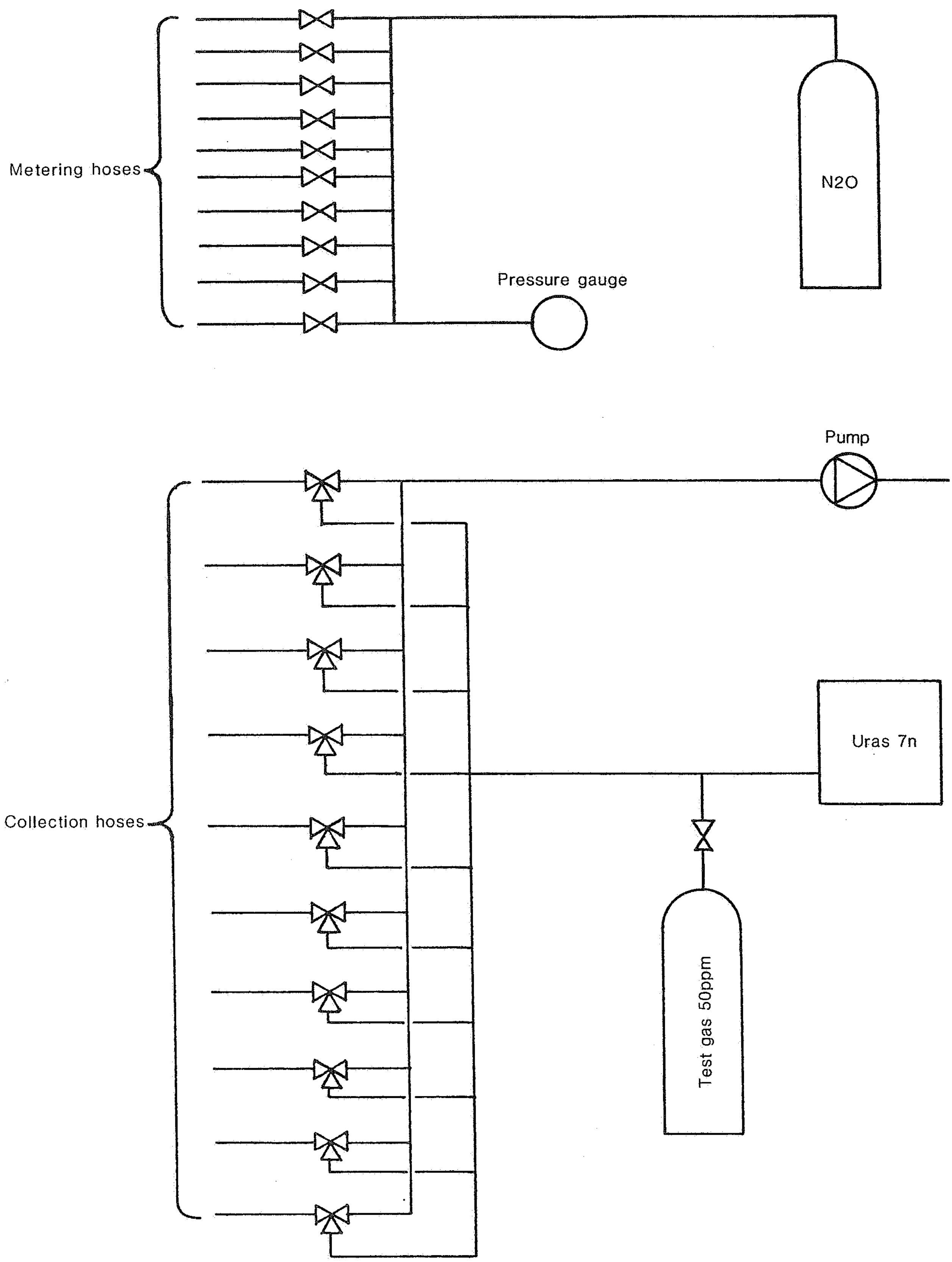


FIGURE 1a

Measurements from a $53m^3$ TI office, room no. 2055 with I and PIA adjustment of jets

Date: 81.08.14.

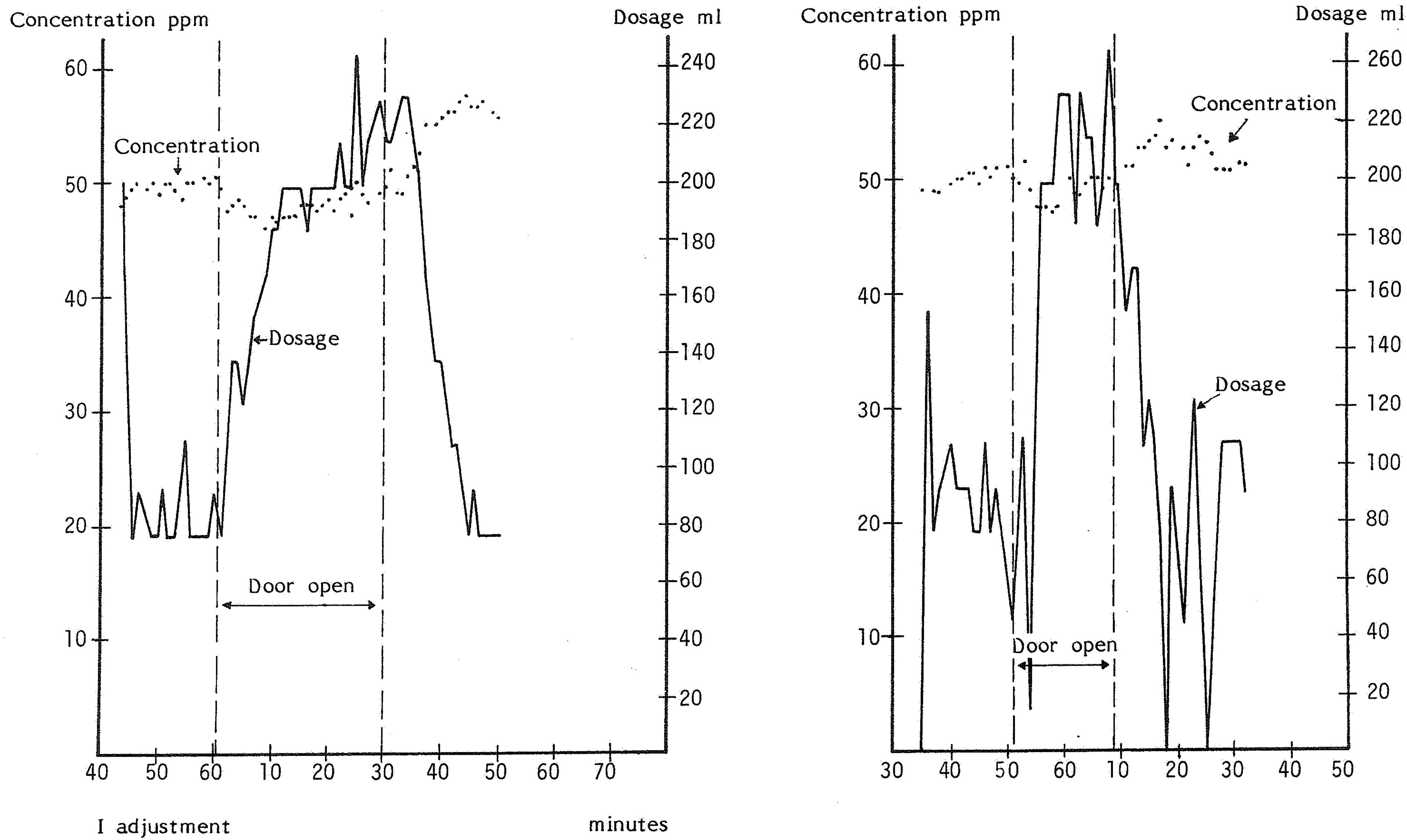


FIGURE 2

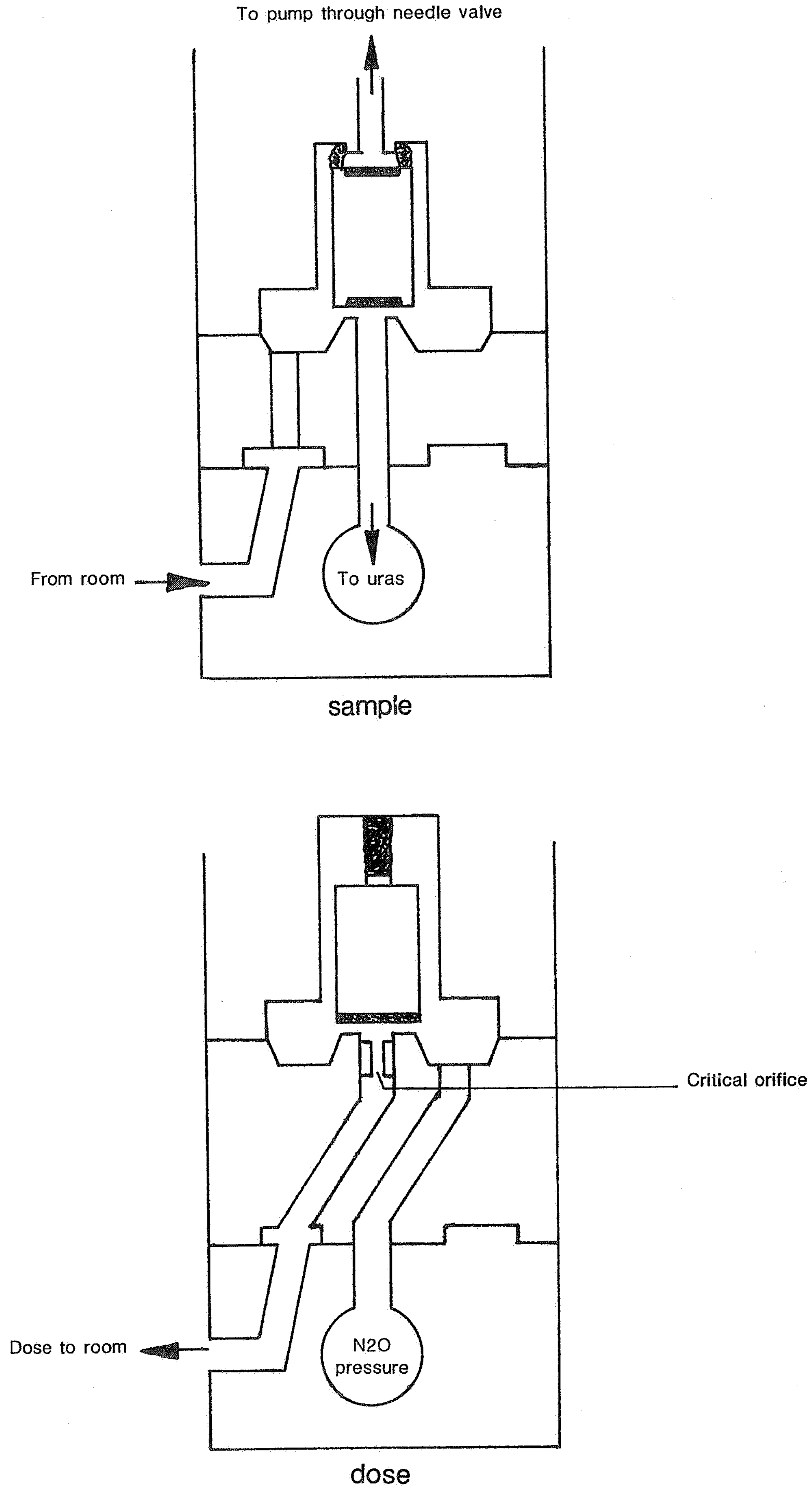
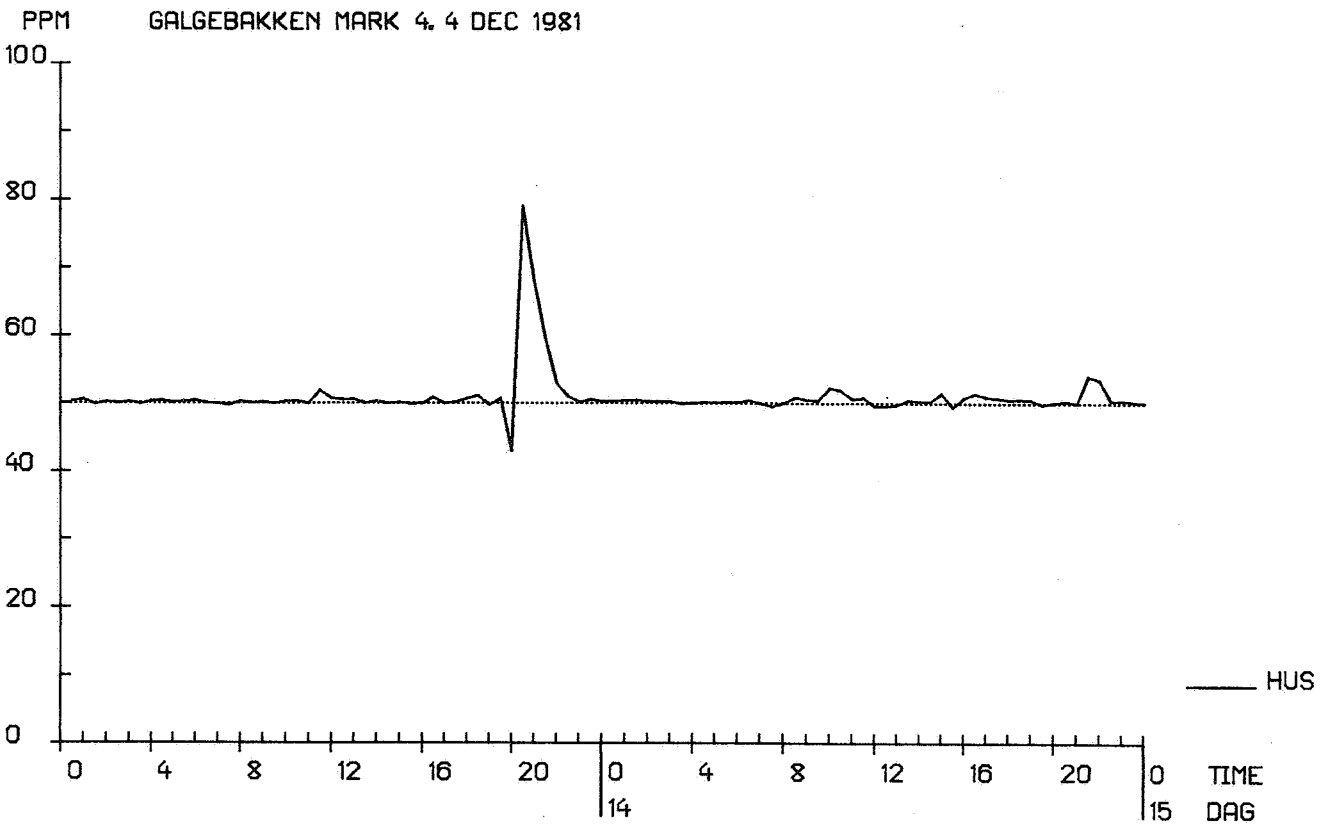

To pump through needle valve
From room
To uras
sample
Critical orifice
Dose to room
N2O
pressure
dose

FIGURE 3

FIGURE 4: Tracer gas concentration (a) whole house



(b) individual room

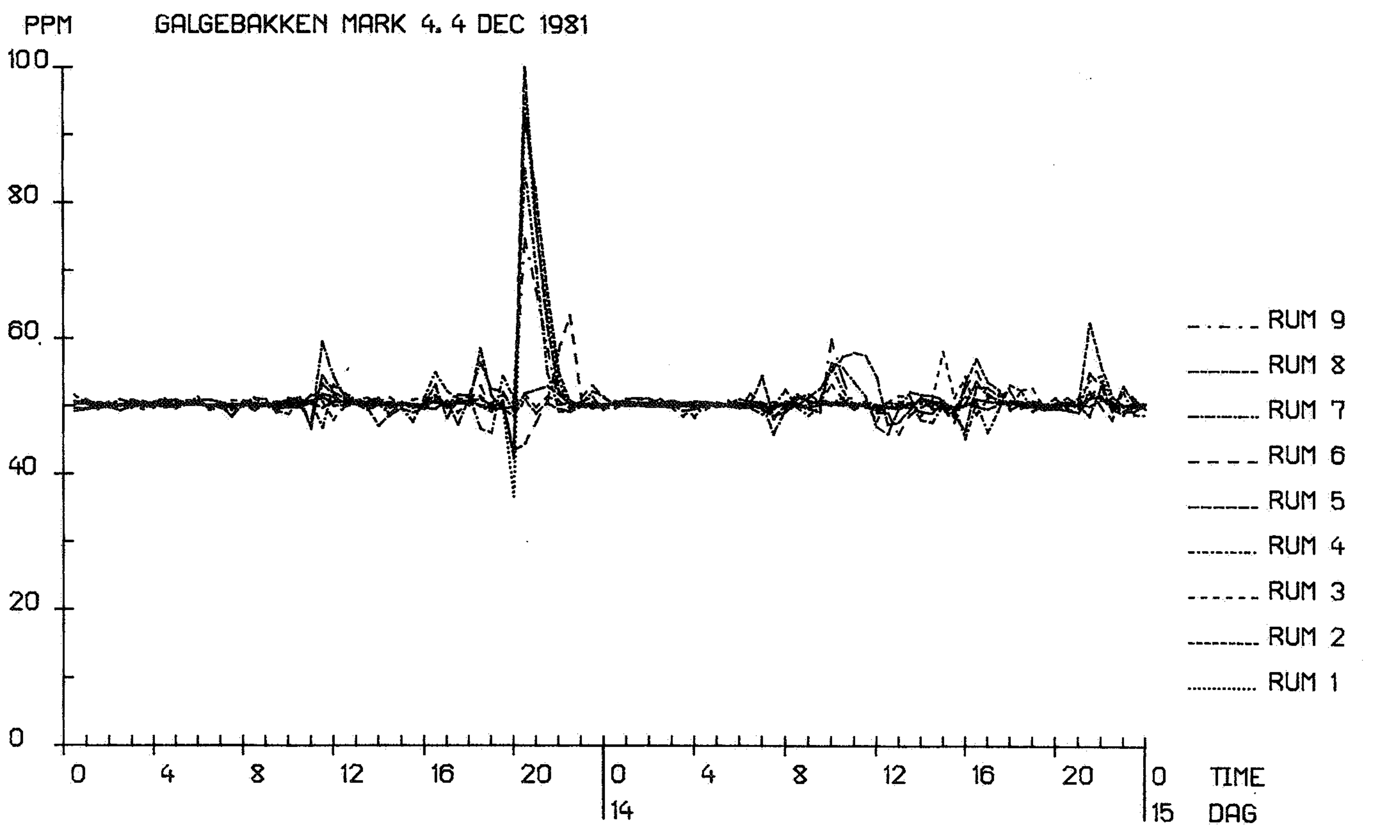
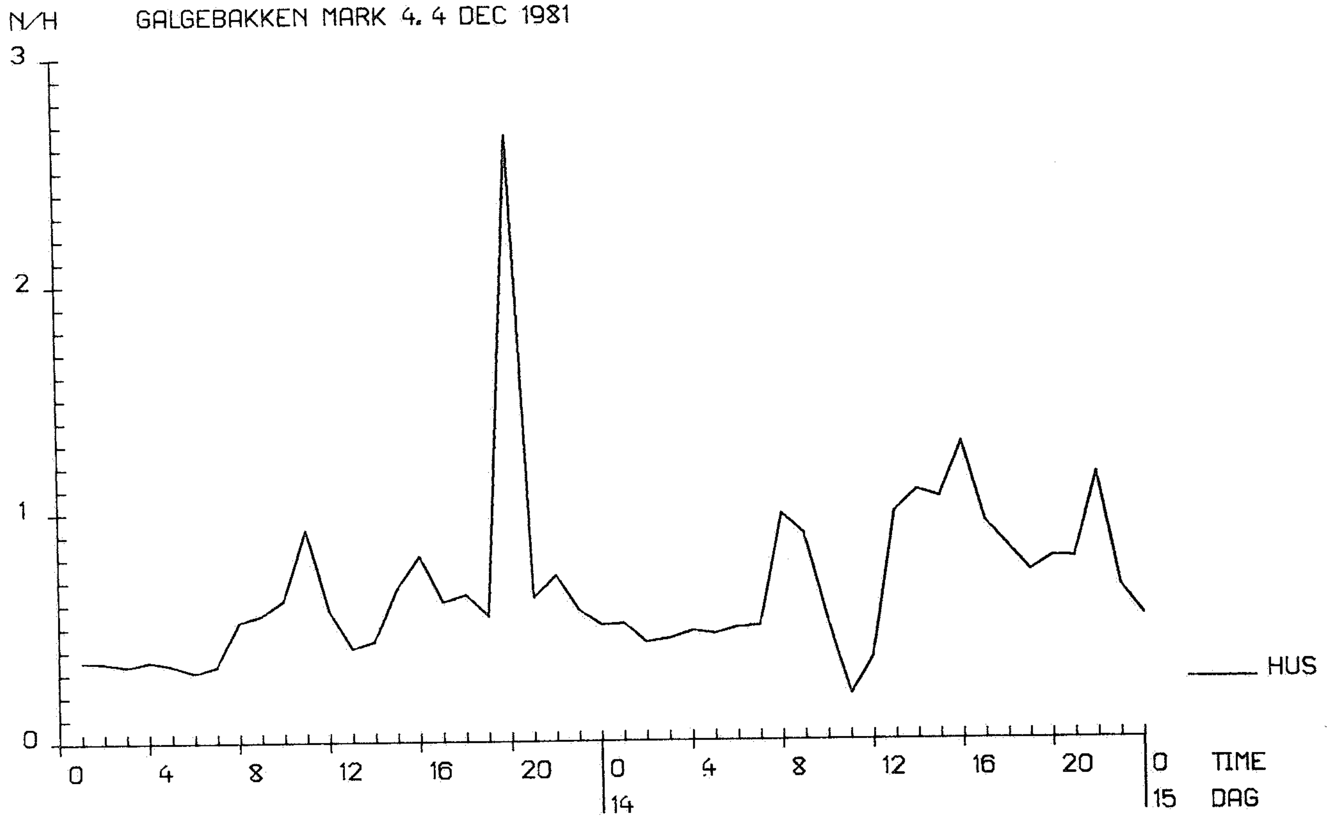
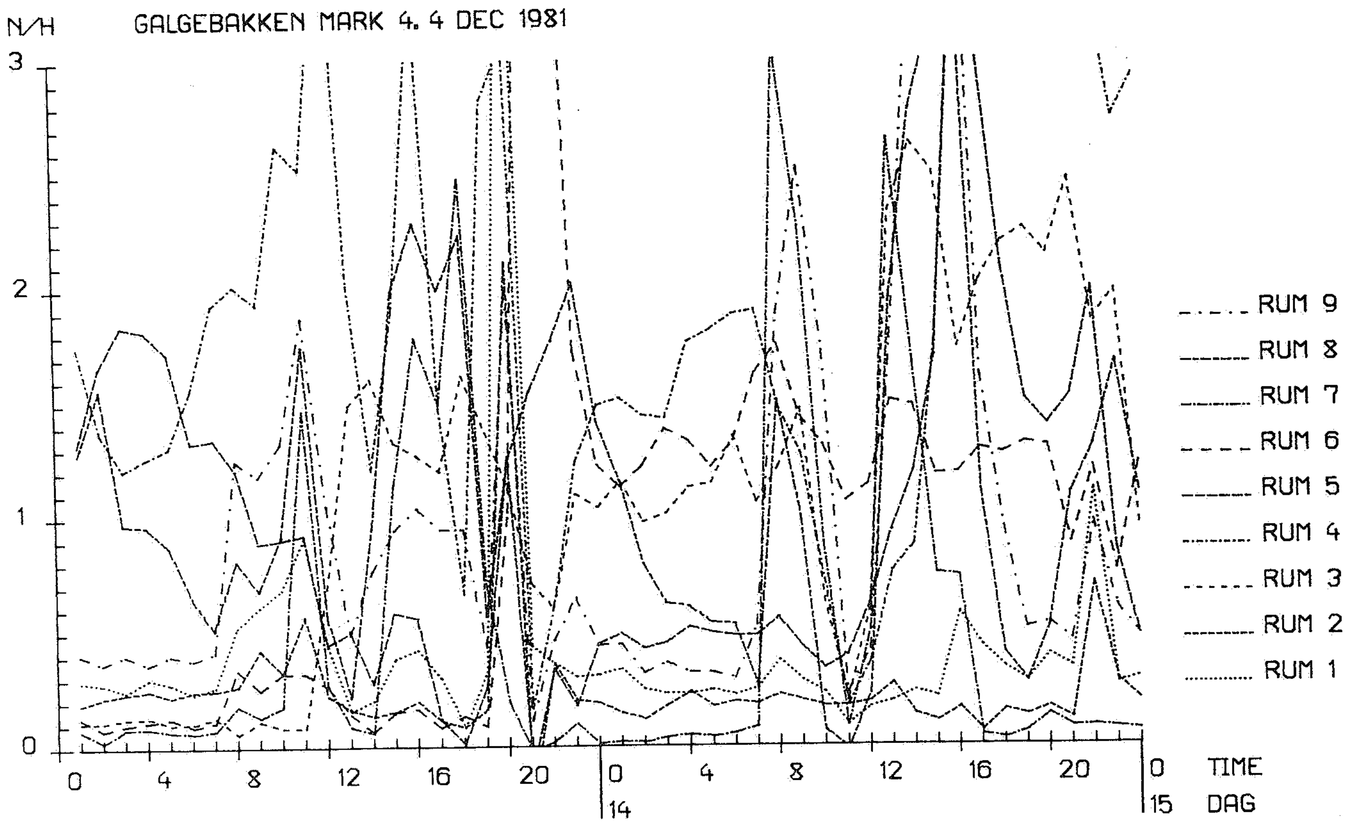


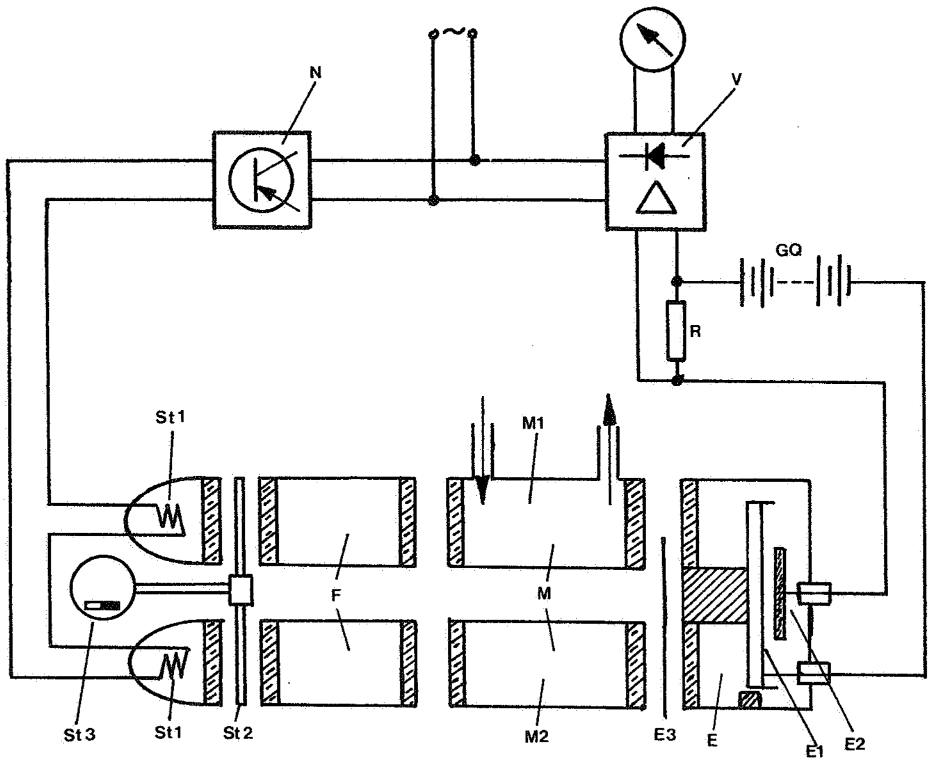
FIGURE 5: Air change rate (a) whole house



(b) individual room



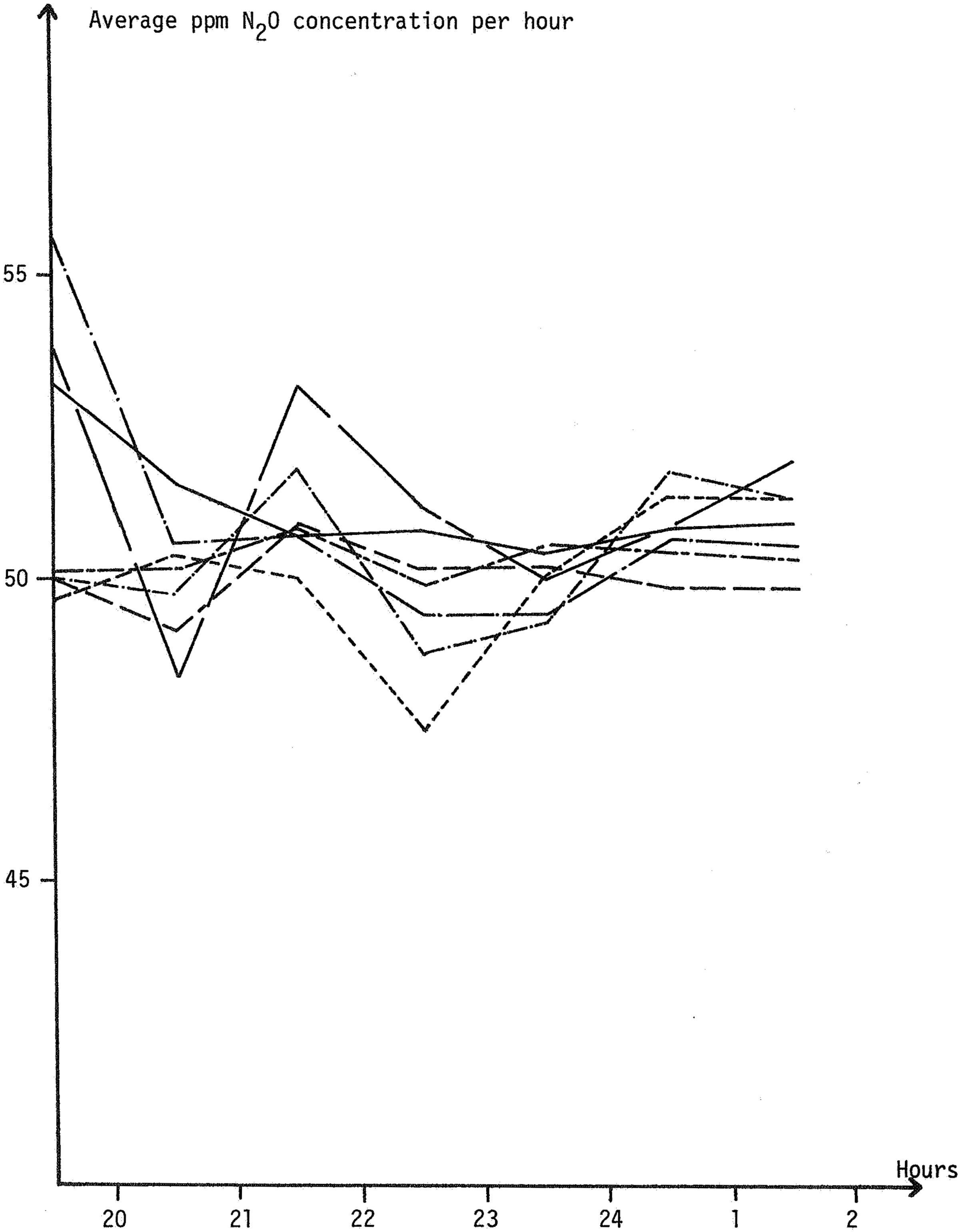
Basic diagram of the infrared gas analyser Uras 7 N



E	Receiver
E1	Condenser diaphragm
E2	Counter electrode
E3	Receiver shutter
F	Filter cell
GQ	Direct voltage source
M	Measuring cell
M1	Analysis chamber
M2	Reference chamber
R	High-impedance resistor
St1	Radiation sources
St2	Shutter wheel
St3	Shutter wheel motor
V	Amplifier
N	Mains stabilisation

FIGURE 6

Measurements taken while house was occupied on 10-11 September 1981 between 10.00 and 11.00



Location: Ringstedvej 20

FIGURE 7