BUILDINGS: LARGE SCALE KITCHEN RANGE HOODS - HOOD EFFICIENCY AND PRESSURE DROP

UDC 643.3

Key words: Hood efficiency, pressure drop, tracer gas, large scale kitchen range hoods, test method

1 SCOPE

This test provides a method of measuring hood efficiency and pressure drop for large scale kitchen range hoods.

2 FIELD OF APPLICATION

The method is to be used under well defined laboratory testing conditions, with regard to:

- Where and how the air enters and leaves the test space.
- Internal heat sources (surface temperature, energy consumption etc).
- The size and interior design of the test space.

3 REFERENCES

1.SS ISO 5221 Guide to methods of measuring air flow rate in an air handling duct.

4 DEFINITIONS

Hood efficiency, η

The hood efficiency is in this test defined as

$$\eta = \frac{m_{ex}}{m_{pr}} \quad [\%]$$

where m_{pr} is the total mass of contamination (tracer gas) produced on a hot surface under the hood for a test period of 25 minutes.

m_{ex} is the mass of the contamination which has been extracted through the hood by the end of the test period.

Equivalent diameter, D_e

$$D_e = \frac{4 * \text{nominal area}}{\pi}$$

where the nominal area is equal to the area of the connecting duct.

5 SAMPLING

Samples shall be taken for at least three different exhaust airflows; 50 %, 100 % and 150 % of a nominal exhaust airflow.

The sampling time interval shall be less than 60 s.

6 METHOD OF TEST

6.1 Principle

The hood shall be mounted in the test space as defined in 6.2.2 and according to the manufacturer's instructions. Under the hood there are to be heat sources which in size and surface temperature simulate the effects of equipment used in an ordinary large scale kitchen. To simulate the movements of someone working in the kitchen there is also a disturbance introduced, consisting of a plate that moves from side to side.

For each airflow the temperatures shall have reached steady state conditions before the test can be carried out.

The test is then accomplished by injecting tracer gas into the test space through a spreader which is placed on a hot surface under the hood. The injection of gas is to continue for 25 minutes. The test space is then shut off from the surrounding area and the tracer gas concentration made homogeneous before being measured. The hood efficiency is then calculated by the use of a simple formula.

The pressure drop as a function of the exhaust airflow can be measured before, during or after this test of the hood efficiency.

Published by NORDTEST Tekniikantie 12 FIN-02150 Espoo FINLAND Tel + 358 9 455 4600 Fax+358 9 4554272

ISSN 0283-7226 Proj. 730-87 www.nordtest.org

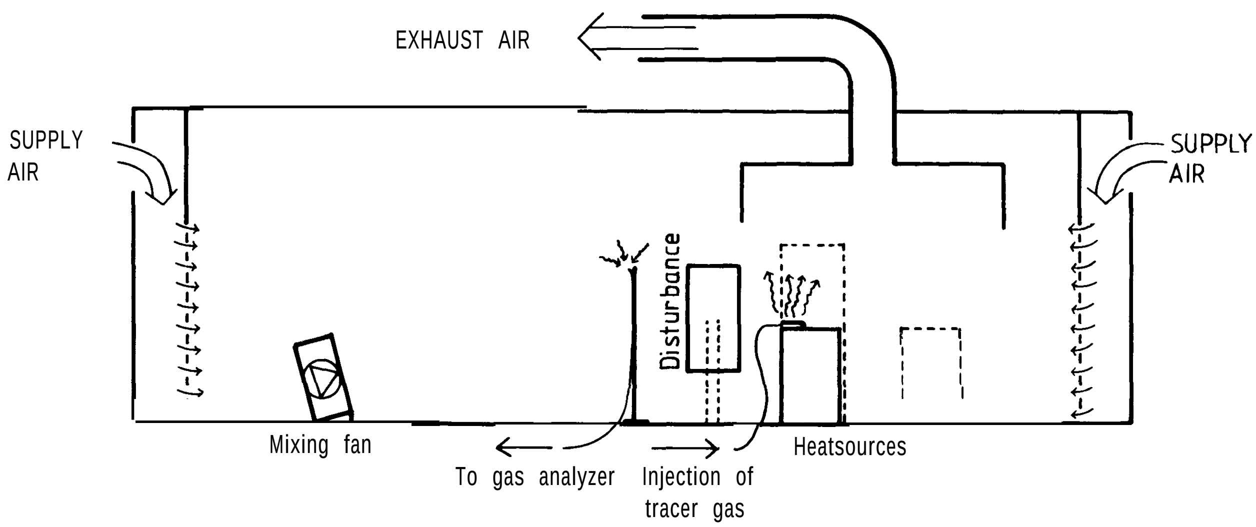

Figure 1 Principle arrangement of test

6.2 Apparatus

6.2.1 Equipment

a) A cylinder with tracer gas (100 % N_2O). The purity of the gas shall be > 99 %. The cylinder shall be provided with a reduction valve and a manometer.

b) A flowmeter, to provide a constant injection of tracer gas into the test space.

c) A spreader, through which the tracer gas is released into the test space.

d) Supply and exhaust air installations (ducts, fans, dampers etc).

e) A gas analyzer, for measuring the tracer gas concentration (e.g. an infrared analyzer). The analyzer shall if necessary be provided with a vapour filter.

f) A pump, to suck air into the analyzer.

g) Tubing of non absorbing material (e.g. nylon or polyethylene) for suction and injection of gas.

h) Heat sources to simulate equipment used in an ordinary large scale kitchen.

i) Equipment for measuring the energy input to the heat sources.

j) Equipment for measuring temperatures (e.g. thermocouples or platinum resistance sensors).

k) Equipment for measuring the exhaust airflow (e.g. according to SS ISO 5221).

l) Equipment for measuring pressure differences (e.g. liquid manometers).

m) A source of disturbance, consisting of a plate which is made to operate from side to side with a fixed velocity and frequency.

n) A stopwatch, for measuring the time of gas injection, and also to check the movements of the disturbing source.

o) A propeller (mixing) fan, to provide a homogeneous concentration of tracer gas in the test space.

6.2.2 Specification of the test space

The test space shall have a volume of 160 ± 50 m^3. The height of the test space shall be 3.0 ± 0.2 m, and the floor rectangular with the dimensions 9.0 x 6.0 (± 1.0 m).

All supply air (with the possible exception of air injected internally in the hood) shall be distributed into the test space in such a way that most of the contaminated air not taken care of by the hood will remain at the ceiling. For this purpose there shall in two or four of the corners be a 0.7 m wide and 1.9 m high plate with a perforation-ratio of about 1:5. It shall form an angle of 45° to the walls and the remaining part up to the ceiling must be covered with unperforated plates. The flow shall be equally distributed amongst the inlets.

All exhaust air must leave the test space through the hood.

Both the supply air inlets and the exhaust air outlet must be provided with dampers to ensure that the test space can be completely shut off from the surroundings.

The leak into the test space (when all dampers are closed) shall at an underpressure of 50 Pa be less than 1.9 m^3/m^2h.

The main heat sources shall be two tables, each 0.9 m high and with a 0.56 x 0.72 (m) iron surface heated with an input of 4 kW electrical energy (providing a temperature of about 340 ... 380 °C in the middle of the surface). The tables shall be covered with plates on all sides all the way down to the floor. A third heatsource shall be made of metal plates 1.7 m high, with both sides 0.6 m and given an input of 0.3 kW, evenly distributed over its surface.

The spreader shall be placed at the outer corner of one of the tables. Its design is described in Figure 2.

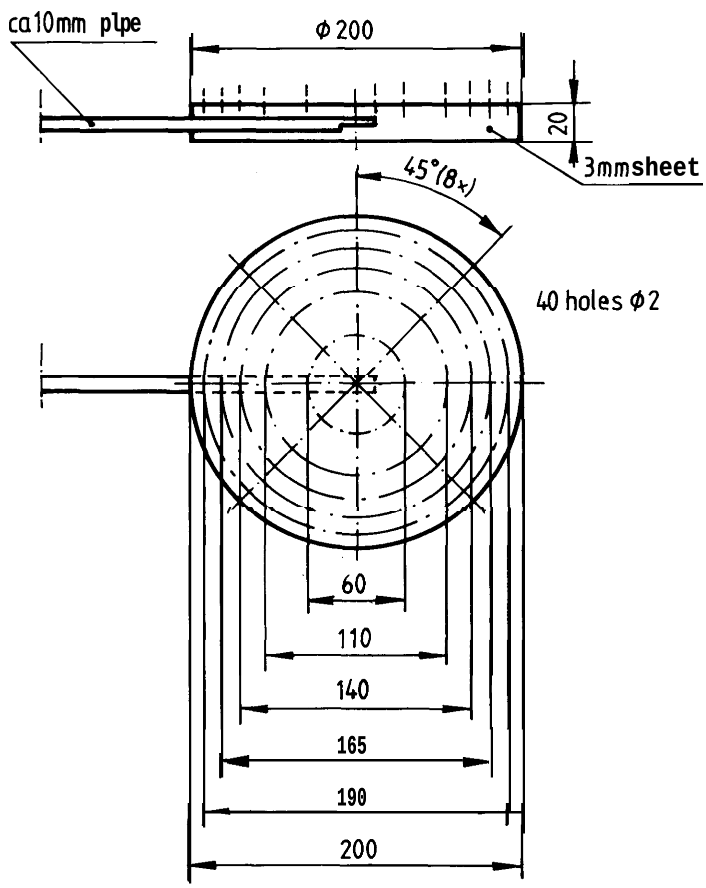

Figure 2 Design of the spreader

The disturbing source shall consist of a 0.5 m wide and 1.0 m high plate with its centre 1.0 m above the floor. It shall operate from one end position to the other (a distance of 1.0 m) every 4th second with a constant velocity of 0.5 m/s, except for acceleration and retardation within 0.2 m from the end positions. Its centre shall be 0.65 m out from the centre of the long side of the table on which the spreader is placed.

The minimum distance between the floor and the hood is to be 1.9 m.

a) Centre mounted hood:

The centre of the hood shall be at a distance of 2.5 ± 0.2 m out from the middle of one of the short sides of the test space. The hood is not to be closer to any of the test space walls than 1.1 m.

The two tables shall be placed in opposite corners and with their sides 0.4 m inside the rectangle made from the vertical projection of the hood outline. The third heat source shall be placed in one of the remaining corners, also with its sides 0.4 m inside the hood outline.

Supply air inlets shall be mounted in all four corners.

The specified positions of heat sources, spreaders etc are illustrated for a centre mounted hood in Figure 3.

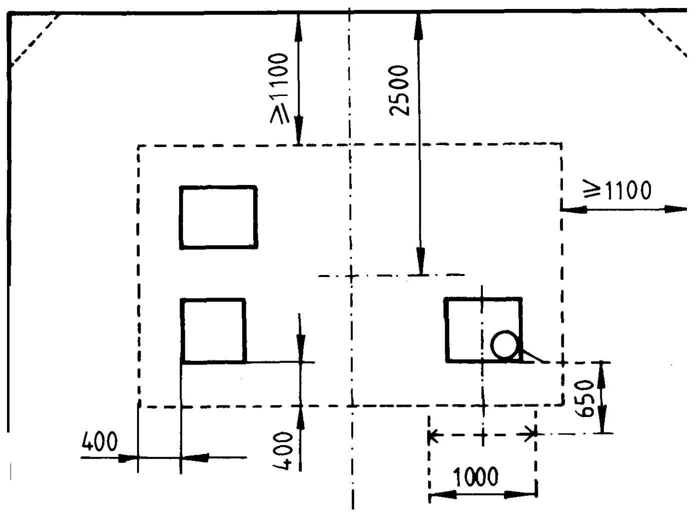

Figure 3 Centre mounted hood

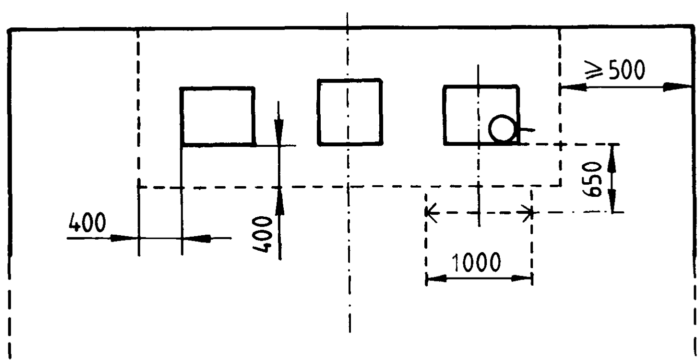

Figure 4 Wall mounted hood

b) Wall mounted hood:

The hood shall be mounted at the middle of one of the short sides of the test space.

The sides of the hood are not to be closer than 0.5 m to the test space walls.

The tables shall be placed with their sides 0.4 m inside the two corners made from the vertical projection of the hood outline. The third heat source shall be placed in the middle between the tables and also with its side 0.4 m inside the hood outline.

Supply air inlets shall be mounted in the two corners at the opposite short side from the one on which the hood is mounted.

The specified positions of heat sources, spreaders etc are illustrated for a wall mounted hood in Figure 4.

6.3 Preparation of test samples

The temperature (both in the air and on the surfaces in the test space) must have reached steady state conditions before the tracer gas is injected. To achieve steady state conditions the heat sources must be switched on a couple of hours before the test. Steady state conditions have been reached when the measured temperature of the exhaust air has been within ±0.5 °C for 25 minutes at the airflow for which the samples are to be taken. The measured surface temperatures of the heat sources shall be within ± 5 °C during this period.

The temperature sensors must be shielded from the heat radiation coming from the heat sources.

The incoming air is to have a temperature of 20 ± 2 °C and must not be allowed to be contaminated with tracer gas before it enters the test space.

Any background level of tracer gas concentration measured in the supply air must be constant (± 2 ppm) during the time of the test and subtracted from the values measured in the test space.

To ensure that the gas analyzer has reached its working temperature, it shall be switched on a few hours before the test.

The analyzer shall be calibrated (e.g. with the aid of calibration gas) within ± 2 ppm, both at zero concentration and at an estimated maximum concentration (about 100 ... 300 ppm).

The propeller fan shall be directed in such a way that the air from the floor level will be thoroughly mixed with the air at the ceiling. The fan must be large enough to ensure that homogeneous concentration can be reached within 5 minutes.

The air which is extracted from the test space and into the gas analyzer shall be recirculated back into the test space.

6.4 Procedure

a) Set the exhaust airflow (q_{exh}) and wait for the temperatures to reach steady state conditions, which may take about half an hour. Air temperatures shall be measured in all supply air inlets, in the middle of the test space and in the exhaust air outlet. Temperatures shall be measured at the centre of the top surface of each heat source.

In the case of internal injection of supply air, also this airflow (q_{inj}) must be set and measured.

b) Measure the pressure drop (dp_{hood}). This is the pressure difference between the static pressure in the centre of the test space and the static pressure of the exhaust air, measured 1.5 D_e upstream from where the duct is mounted to the hood. The result shall be converted into standard air conditions ρ_{air} = 1.2 kg/m^3).

This measurement can also be made separately before or after the other measurements of the procedure.

c) Measure the background level of tracer gas concentration (C_b).

d) Inject tracer gas through the spreader and into the test space for 25 minutes (1500 s). The mass flow must be held constant at 2.2 * 10^{-4} kg/s during the whole time of injection.

e) At the same time as the gas liberation is stopped, the test space is shut off from the surrounding area (i.e. all fans stopped and all dampers closed). The heat sources shall remain on.

f) Start the mixing fan and allow the tracer gas concentration in the test space to become homogeneous. To determine when homogeneous conditions have been reached, the tracer gas concentration in the test space shall be monitored during the whole time of mixing. Homogeneous concentration can be assumed to have taken place when 2 minutes of sampling has given the same result (±1 ppm).

g) Measure the tracer gas concentration (C_a) and the air temperature (t) in the centre of the test space for 5 minutes. The concentration samples shall then be almost constant and any tendency to increase or decrease shall be extrapolated back to the point of time when the gas injection was stopped. The increase of temperature (due to the heat sources) shall also be extrapolated back in the same manner.

h) If measurements at another airflow are to follow, the test space shall be thoroughly ventilated from tracer gas before starting at a) again. The room shall be ventilated until the background tracer gas level is back to what was measured at c) (±2 ppm). (To minimize the necessary time of ventilating, it is a good idea to start with the largest flow first.)

6.5 Expression of results

Airflows (q) shall be converted into the volume flow corresponding to standard air conditions (ρ_{air} = 1.2 kg/m^3) and given in m^3/s.

Hood efficiency (η) is calculated by formula:

$$h = 100 - \frac{\rho * C * V}{q_m * \tau} * 10^{-4} \qquad [\%]$$

where ρ is the density of the gas calculated by the formula:

$$\rho = 1.872 * \frac{P_{atm}}{101.3} * \frac{288}{273+t} \qquad [kg/m^3]$$

where P_{atm} is the atmospheric pressure in kPa and t is the air temperature in °C, measured in 6.4 g.

$$C = C_a - C_b \qquad [ppm]$$

where C_a = the tracer gas concentration measured in 6.4 g and C_b is the background level measured in 6.4 c.

C_b = the background level measured in 6.4.c.

V = the volume of the test space given in m^3. It is defined as its height x length x width (m). The volume of the hood, heat sources, supply air inlets etc is not to be taken into account.

q_m = the mass flow of liberated tracer gas given in kg/s.

τ = the time of gas liberation given in s.

6.6 Uncertainty

The uncertainty of the hood efficiency is calculated by the formula:

$$\Delta\eta = \frac{\rho \cdot C \cdot V}{q_m \cdot \tau} \cdot 10^{-4} \sqrt{\left(\frac{\Delta\rho}{\rho}\right)^2 + \left(\frac{\Delta C}{C}\right)^2 + \left(\frac{\Delta V}{V}\right)^2 + \left(\frac{\Delta q_m}{q_m}\right)^2 + \left(\frac{\Delta\tau}{\tau}\right)^2}$$

where
$\Delta\rho$ = the uncertainty for the density of ρ (< 0.05 kg/m^3)
ΔC = the uncertainty for the concentration C (< 20 ppm)
ΔV = the uncertainty for the volume V (< 5 m^3)
Δq_m = the uncertainty for the mass flow q_m ($< 5 * 10^{-6}$ kg/s)
$\Delta\tau$ = the uncertainty for the time t (< 30 s)

Other measurements shall be made within the following limits of uncertainty.

Airflow	±3 %
Atmospheric pressure	±0.5 kPa
Pressure drop	±2 Pa
Energy consumption	±1 %
Surface temperature	±5 K
Air temperature	±0.2 K

6.7 Test Report

The test report shall include the following information, if relevant:

a) Name and address of the testing laboratory

b) Identification number of the test report

c) Name and address of the organization or the person who ordered the test

d) Purpose of the test

e) Method of sampling and other circumstances (date and person responsible for the sampling)

f) Name or other identification marks of the tested object

h) Description of the tested object

i) Date of supply of the tested object

j) Date of the test

k) Test method

l) Conditioning of the test specimens, environmental data during the test (temperature, pressure, RH, etc)

m) Identification of the test equipment and instruments used

n) Any deviations from the test method

o) Test results (use SI units)

p) Inaccuracy or uncertainty of the test result

q) Date and signature