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Ventilation and Humidity in Bathrooms

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Synopsis

A laboratory investigation has been made in a modern Swedish bathroom continuously ventilated by an exhaust fan. The tests consisted of measurements of the humidity, temperature and local mean-age after a standard shower. The measurements were mainly made in a non-heated installation.

The maximum relative humidity, in a bathroom , is approximately constant at a given air temperature. This does not seem to be true for the measurement under the bath where the maximum moisture content was found to be constant.

The most accurate measurement was made immediately after the shower. The best results were found by increasing the airflow .The best advantage is the amount of the vapour spread in the room decreases. The increased airflow did not have any effect of the moisture content in the middle of the room and under the bath.

The use of an infrared heater also shows an improved reduction of the moisture content in the middle of the room and extracted moisture. The use of a radiator only showed a reduction of the moisture content in the middle of the room.

One hour after a shower approximately 240 g moisture is extracted and after two hours approximately 340 g moisture is extracted from the bathroom.The extraction of moisture will be much lower during summer when the moisture content in the supply air is high. To reduce the moisture problem in summertime it may be worth considering installing a dehumifier since an increased airflow only will give a small reduction.

List of symbols

Parameters:

q	Air flow (l/s)
t *	Temperature (°C)
RH*	Relative humidity (%)
x*	Moisture content in the air (g/kg)
xa*	Added moisture content, xa* = x*-xin (g/kg)
m	Extracted moisture (g)
m(1)	Extracted moisture during one hour (g)
m(2)	Extracted moisture during two hours (g)
P	Electrical power (W)

Where (*) represents the following locations:

in	Measuring point in the supply air terminal device
out	Measuring point in the exhaust air terminal device
r.1	Measuring point 0.1 m above the floor in the room
r1.1	Measuring point 1.1 m above the floor in the room
r2.0	Measuring point 2.0 m above the floor in the room
b.3	Measuring point 0.3 m above the floor under the bath

1 Introduction

Moisture problems are very common in modern Swedish bathrooms although they are continuously ventilated by an exhaust fan. Condensation on surfaces and high humidity levels are common problems, which may cause rot and mould problems.

The problems usually occur in summertime when the supply air has a very high humidity or in the winter when the wallsurface temperature is low. A high humidity level will also cause discomfort for the user.

When examining moisture problems it is important to know the maximum humidity level is and the time of exposure.

This paper is based on laboratory measurements of a bathroom module. A report is given in [Ref 4].

2 Test procedure

The tests were carried out using a three minute standard shower, 40 °C and 27 l of water [Ref 2], with an airflow rate of 10, 15 and 20 l/s respectively.

The tests were made with three different kinds of heating systems:

- no space heating at all
- a wall mounted electric radiator (R)
- a roof mounted infrared heater (IRH)

As a reference case the 15 l/s airflow with no space heating was chosen according to the Swedish building code.

The tests consisted of measurements of:

- air and surface temperature
- humidity
- local mean-age of the air

2.1 Sampling and preparation

The bathroom made for exhibitions [Ref 1], measures 1.92 x 3.24 x 2.23 m [W x L x H]. Supply air enters the room though the opening between the doorleaf and the doorstep. The air is extracted through an exhaust air terminal device located in the wall over the bath. In order to simulate the presence of a person, 100 W of heat is generated by an electric heater located in the bathtub. The location of the measuring points is shown in figure 2.1

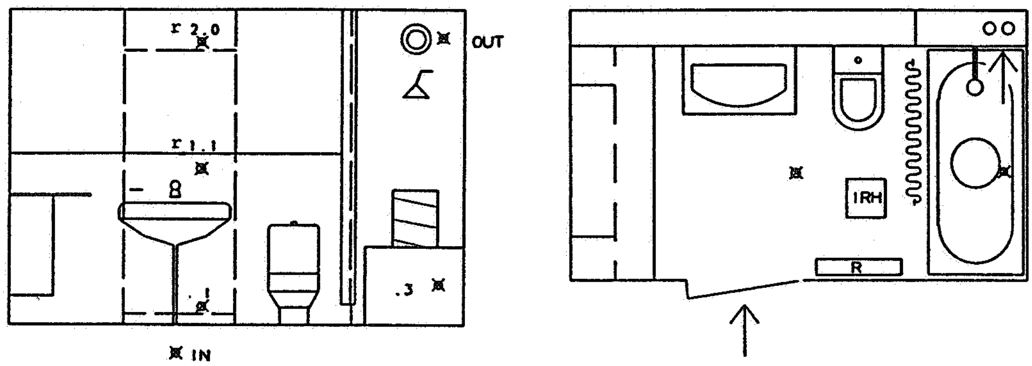

Figure 2.1 Location of measuring points in the bathroom module (See also list of symbols)

Humidity and temperature measurements were made in the supply and exhaust air terminal device, at the height 1.1 m and 0.1 m in the middle of the room and 0.3 m above the floor under the bath. The accuracy of the humidity measurements is better than +/- 5 % RH.

Temperature measurements were made in 8 different points between 0.1 and 2 m above the floor in the room and on the surfaces of the walls and the floor.

Local mean-age of air was measured in the exhaust air terminal device, under the bath and in 6 points between 0.1 m and 2 m above the floor in the room. The measurements were made with nitrous oxide according to [Ref 5] and [Ref 6].

Each test where measured during a period of at least two hours.

3 Results and discussion

3.1 Introduction

The moisture content in the air is a combination of the vapour production from hot water in the shower and evaporation from the wet surfaces. The vapour from the shower is assumed to follow the same slope as the logarithmic concentration-time decay curve of tracergas measurements.The wet surface will then yield a moisture exchange depending on the moisture content in the boundary layer.

The principal humidity curves expressed as relative humidity in the air after a standard shower are shown in figure 3.1.

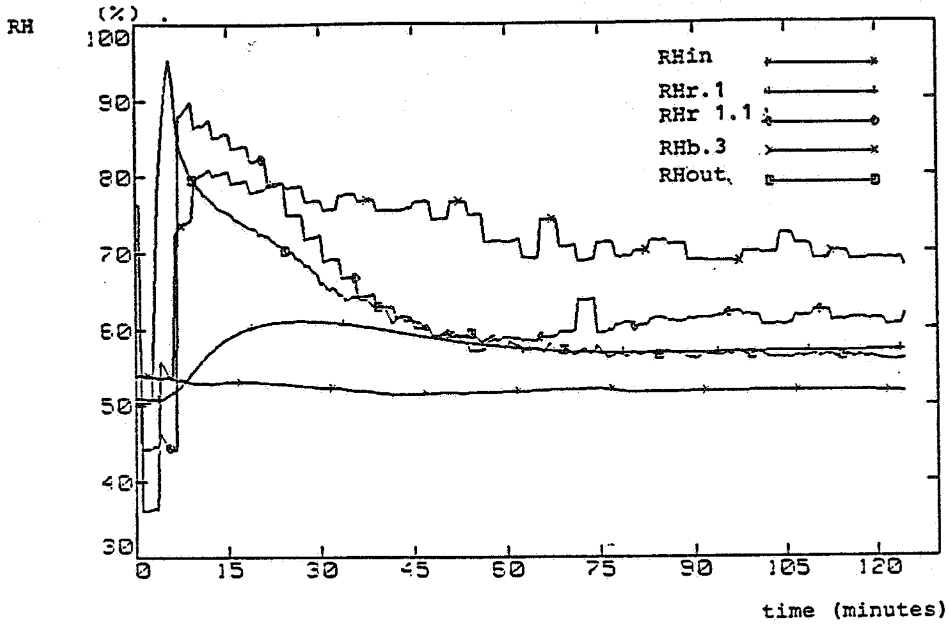

Figure 3.1 Measured humidity transients in a bathroom for the reference case .(15 l/s exhaust airflow ,no space heating)

The maximum humidity is measured in the exhaust air terminal device. The humidity rises to 80 % RH almost immediately and reaches 95-98 % RH when the shower is over. After a couple of minutes the maximum value in the middle of the room, approximately 90 % RH, is reached. After additional minutes the maximum value under the bath , 70-80 % RH, is reached.

The humidity decreases faster in the exhaust air terminal device and in the middle of the room than under the bath.From approximately 15 minutes after the end of the shower the highest humidity level in the room is found under the bath.

This is an example of a typical test run, but the measurements show wide variations, especially under the bath. Droplets of water drain down the wall during and after the shower. Another difficulty is the influence of the air temperature and the humidity in the supplyair.

3.2 Airflow patterns

The airflow was supplied through a 32 mm slot under the door. The construction of the doorstep formed a large whirl which gave a wellmixed ventilation with an air-exchange efficiency of 55 to 60 %. The higher value was found when the supply air temperature difference was decreased from -0.5 to -2 °C below the room temperature tr1.1.

The local mean-age of the air showed small variations. in the heated and non-heated referance case it was calculated to be 0.22 hours except under the bath,where it was 0.24 hours.

The influence of the airflow is shown i figure 3.2

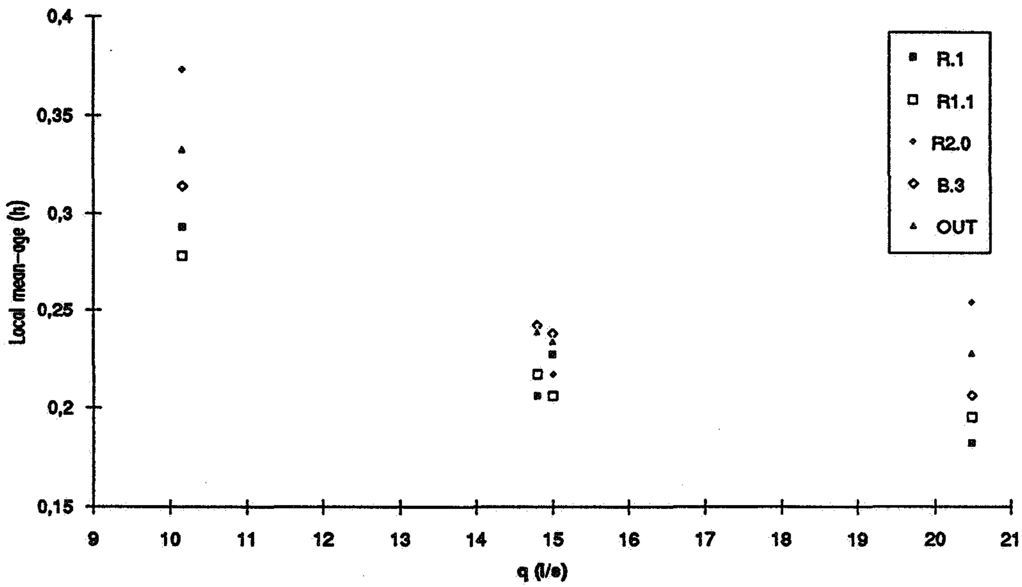

Figure 3.2 Measured mean-age of air, reference case i.e. no space heating.

3.3 Maximum moisture content directly after the shower

The majority of the measurements were made in the non heated bathroom with an airflow of 15 l/s (reference case). The water on the surface was measured to be approximately 0.3 kg after a standard shower.

The maximum moisture content in the air, at reference airflow, was compared with all the measurements .It was found that the level is a function of the room temperature and the moisture content in the supply air.The values are shown in figure 3.3.

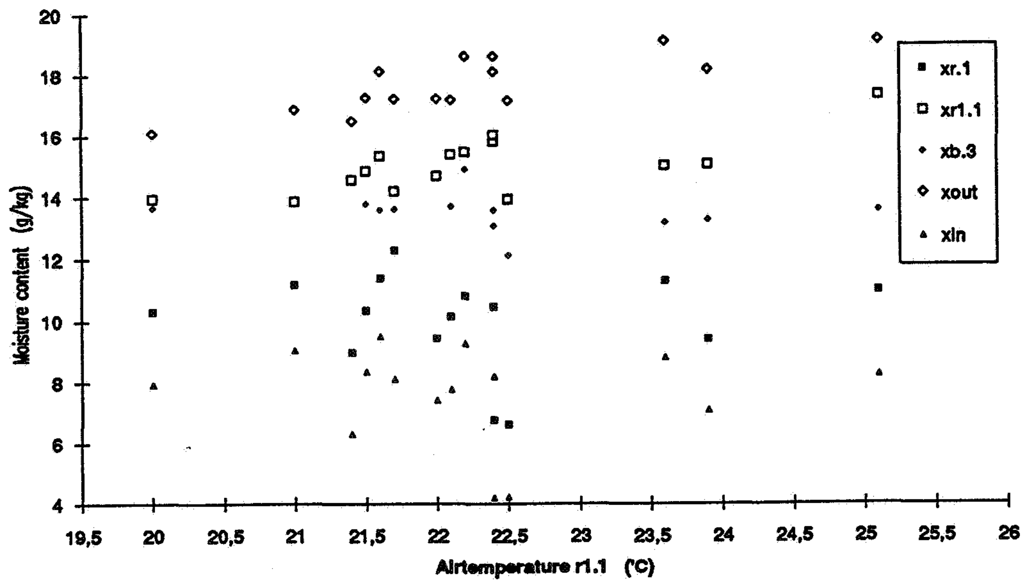

Figure 3.3 Maximum moisture content at different air temperature,exhaust airflow 15 l/s .

The maximum of relative humidity is approximately constant at a given air temperature except under bath where the maximum moisture content is constant ,14 g/kg .

The slope of the logarithmic added moisture-time curve was found to decrease with time.The first half an hour of the measurements showed the highest degree of accuracy.

If a mixed ventilation is assumed, the slope will correspond to the local mean-age of air. The values are shown in table 3.1

Table 3.1The inverted slope of the added moisture content

q	Heater	xaout	xab.3	xar1.1
(l/s)		(h)	(h)	(h)
10	---	0.8	2.6	1.2
15	---	0.6	1.2	0.8
20	---	0.3	1.3	0.8
15	IRH	0.4	?	0.4
15	R	0.6	?	0.3

The best results for the exhaust air terminal device were found when the airflow was increased and by use of a infrared heater. The effect of an increased airflow is much higher for the added moisture than for the local mean-age of air.

The slope in the middle of the room was highly affected in the radiator case and the infrared heater case. In two of the cases no valid slope was found according to the big variations.

3.4 Moisture content in the air with no space heating

One hour after the shower the variations of the slope for the same case increased.To investigate the continued process, the maximum and mean values of the added moisture content in the air were measured for the different positions of the bathroom. The values are shown in figure 3.4

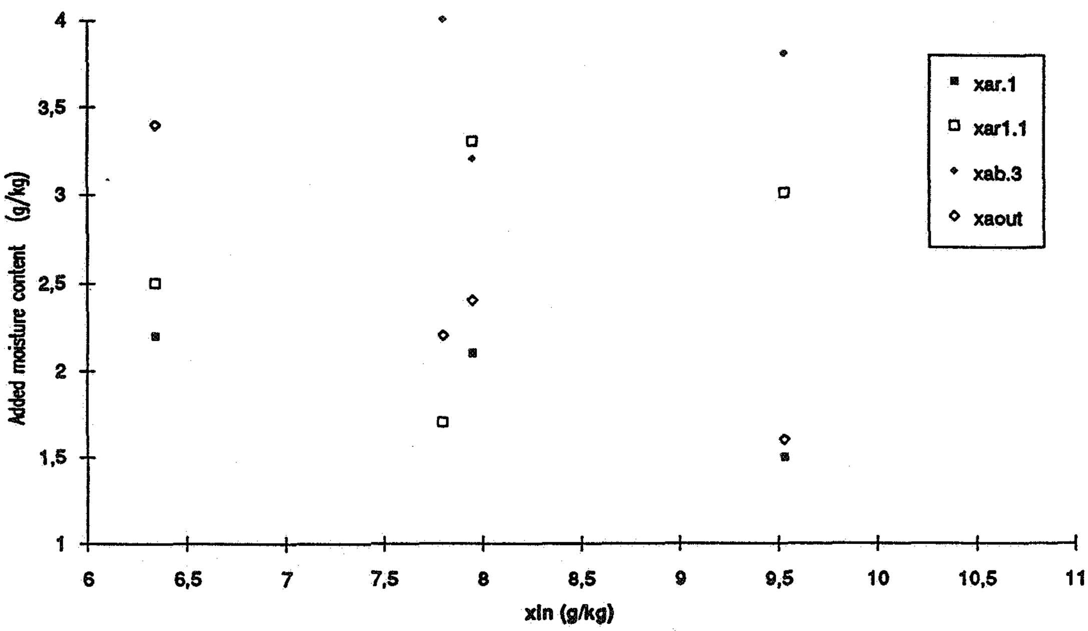

Figure 3.4 Moisture added to the air in the bathroom as a function of the moisture content in the supply air.The values is based on measurement, one hour after the shower for the reference case at an air temperature of 22 °C.

At 0.1 m in the room and in the exhaust ATD a high influence of the moisture content of the supplied air was observed. The measured values at 1.1 m in the room and under the bath were not affected by the supplied air to same extent , but the variation was bigger.

The totally extracted moisture content was calculated. This was repeated for a two hour mean value. The results are given in figure 3.5

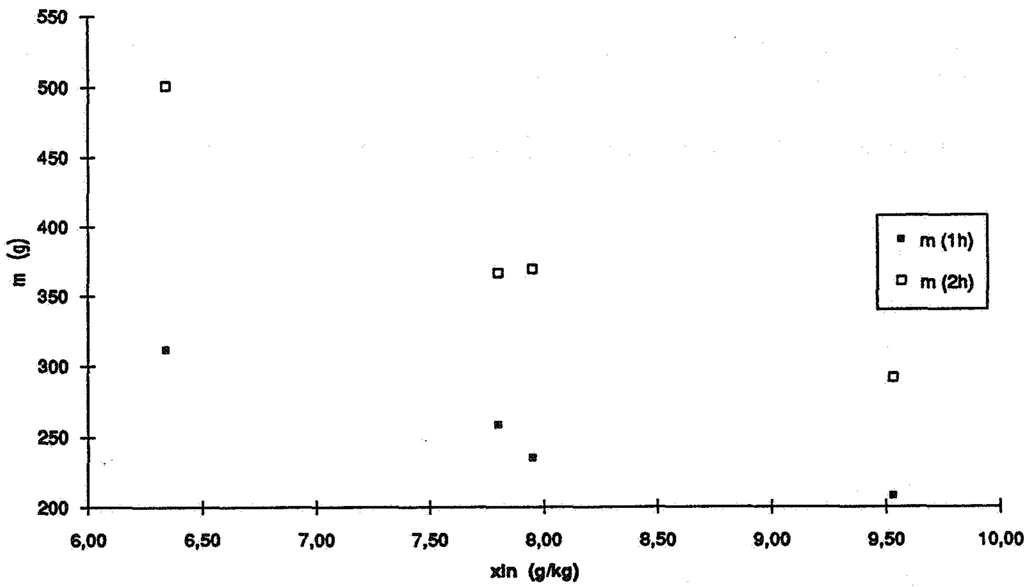

Figure 3.5 Totally extracted moisture as a function of the moisture in the supply air.The values is based on measurement, after one and two hour after the shower for the reference case at an air temperature of 22 °C

A simplified formula of the totally extracted moisture can be defined as

$$m = A \cdot xin^{B} \qquad (1)$$

The constants A and B are given in table 3.2

Table 3.2

Parameter	Constant	Constant
m	A	B
m (1h)	2000	-1.00
m (2h)	5500	-1.31

An air temperature of 22 °C and a relative humidity of 50% RH corresponds to a moisture content of 8.2 g/kg. One hour after the shower approximately 240 g moisture was extracted from the bathroom and after two hours approximately 340 g moisture was extracted.

In order to compare other results with this reference case a non-dimensional relationship is introduced as

$$F = \frac{\text{Measured value} \quad (g/kg)}{\text{reference value*} \quad (g/kg)} \quad (\%) \qquad (2)$$

* the reference value according to formula (1) for a certain moisture content in the supply air.

A decrease in airflow, to 10 l/s, was found to increase the variation in the measured points.

The opposite was found when the airflow increased.The reduction of relative humidity after one hour, was not easily observed except at 0.1 m in the room and in the exhaust air.

The airflow will effect the totally extracted moisture as shown in figure 3.6

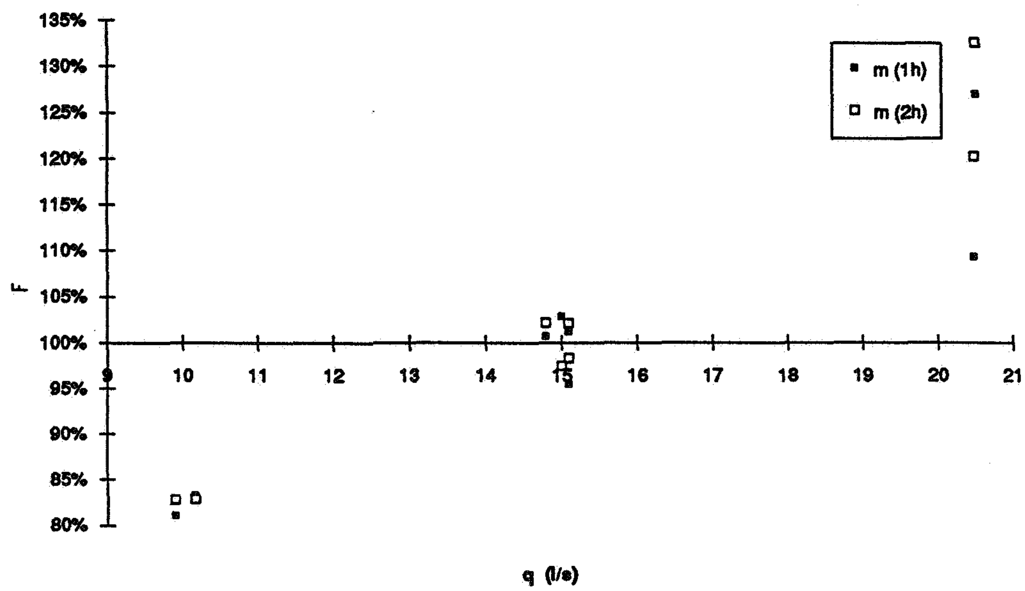

Figure 3.6 Totally extracted moisture (equation 2) after one and two hours as a function of airflows.

Increasing the airflow by 33% will give rise to an increase in the extracted moisture, after one hour with by 20% and after two hours 25% . A 33% decrease in airflow will reduce the extracted moisture with 17% compared with the extracted moisture for the reference airflow 15 l/s.

3.3 Moisture content in the air with space heating

The measurements were repeated with a centrally located infrared heater. As the bathroom module was not insulated these measurements do not have the same degree of accuracy. The extracted moisture content, in different locations, varied to a grat extent. The influence of totally extracted moisture and electric power is shown infigure 3.7

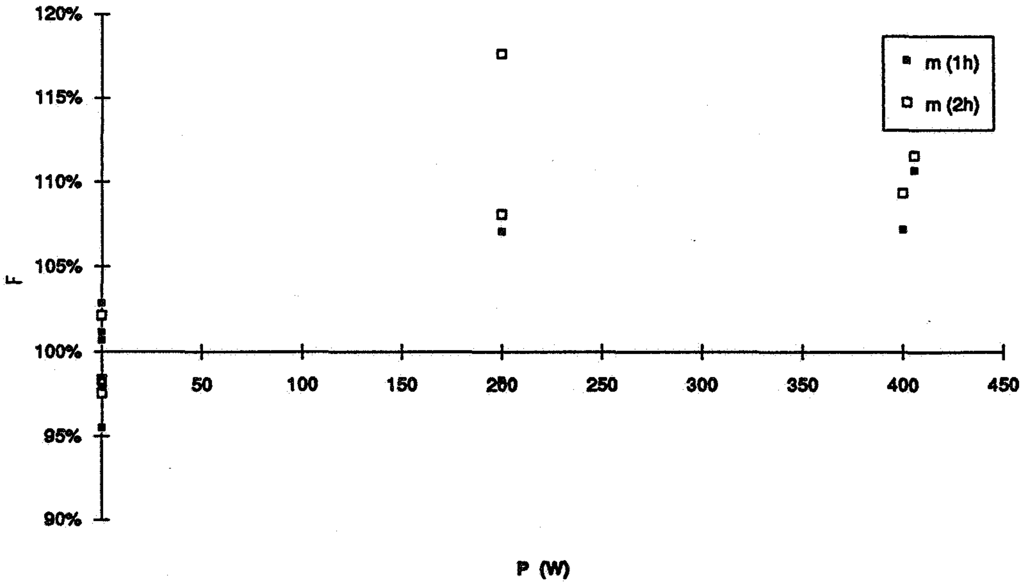

Figure 3.7 The relationship between the reference and the infrared heater case. Totally extracted moisture after one and two hours at different electrical power.

The electrical power corresponds to an air temperature , tr1.1 ,of 23 and 24 °C .

The measurements were also made with an electric radiator. As the moisture content in two of the measurements was very low, xin = 4.3 g/kg , the formula (1) will give higher inaccuracy. The influence of the air temperatures is shown in figure 3.8

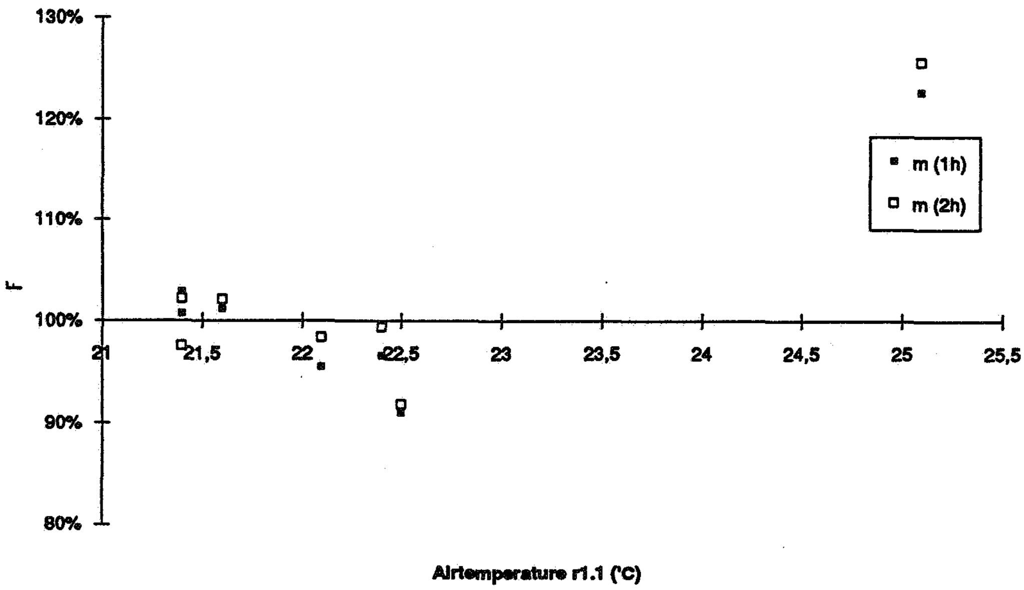

Figure 3.8 The relationship between the reference and the radiator case. Totally extracted moisture after one and two hours at different air temperature.(the air temperature of the radiator case is higher than 22.3 °C.

Between the cases with the infrared heater and the radiator only a small surface temperature difference was found.

4 Conclusions

The process of vafour production from the shower and evaporation from the wet surfaces will be different in different locations.

The maximum relative humidity, in a bathroom , is approximately constant at a given air temperature. This does not seem to be true for the measurement under the bath where the maximum moisture content was found constant. The test results also show that the moisture content , at one hour after a shower, is highly influenced by the moisture content in the supply air.

The most accurate measurement was made directly after the shower. The slope of the added moisture content show that the best results were found by increasing the airflow but the best advantage is the reduction of the vapour spread in the room.

The increased airflow did not have any effect of the moisture content in the middle of the room and under the bath. This was shown by the mean values of added moisture content in the air and in table 3.1 .

The totally extracted moisture was highly affected by an increased airflow as showed by the slope of the logarithmic added moisture-time curve.The use of an infrared heater also show a improved reduction of the moisture content in the middle the room and extracted moisture. No valid slope was found under the bath but the relative humidity found lower due to the increased temperature.The totally extracted moisture also indicate a smaller improvement.

The use of a radiator only showed a reduction of the moisture content in the middle of the room.

One hour after a shower approximately 240 g moisture is extracted and after two hours approximately 340 g moisture is extracted from the bathroom.

The extraction of moisture will be much lower during summer when the moisture content in the supply air is high.This will affect the time of wetness. The same amount of extracted moisture is achieved after one hour with a supply moisture content of 7 g/kg ,as after two hours with a moisture content of 9.5 g/kg.

To reduce the moisture problem in summertime it may be worth considering installing a dehumifier since an increased airflow only will give a small reduction.

Investigations have also been made to examine the effect of the supply air terminal device over the door,another location of the infrared heater and a reduction of the wet surface behind the bath by closing the slot around the bath. A final report is found in reference [4].

Further investigations are planed for a model of moisture content in the different locations of the room which combine the processes, ventilation, vapour from the shower and evaporation from the wet surfaces.

Acknowledgements

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References

[1] Persson, Judit "Hygienrum etapp I" (An Investigation of different layouts of bathroom) Swedish Council for Building Research Report 6´88.

[2] Sundin, Johan "Ventilation i badrum" (An Investigation of ventilation in bathroom) KTH march 1989.

[3] Hansen Sten Olaf "Evaporation from swimming-pools" Proceeding of Roomvent, Oslo, Norway 1990.

[4] Fransson,Jan I "Hygienrum etapp II"(An Investigation of ventilation and humidity in a bathroom) Swedish Council for Building Research Report *´91.To be published.

[5]Nordtest Method "Buildings-Ventilation , local mean age"NT VVS 019

[6]Nordtest Method "Buildings-Ventilation , mean age of air"NT VVS 047