Energy
Management AB
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Test Report

Carry-over test of three SWEGON rotary heat recovery sections

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Summary

Three regenerative (rotary) heat exchangers were tested for carry-over of exhaust air to supply air, according to the European standard EN 308:1997. The tests were carried out 2011-04-28 at Swegon Test Center in Kvänum Sweden, by Lars Ekberg, CIT Energy Management AB.

The tested objects:

GOLD 08 installed in test-rig	- New rotary heat exchanger
Compact Unit	- Unit in operation since 2008
PM Luft/GOLD-3-4-3	- Unit in operation since mid nineties

The units were adjusted according to Swegons instructions and the tests were carried out at 9-13 Pa higher pressure in the supply air duct compared to the exhaust air duct. The rotors were operated at nominal speed. The exhaust and supply mass flow rates were documented.

Tracer gas - dinitrogen oxide - was injected far upstream of the heat exchangers, and the concentration mixing (uniformity) was verified by measurements in multiple points of the cross section of the duct - immediately upstream of the heat exchanger. The tracer gas concentration in the supply air duct was also measured in multiple points of the duct cross section, to verify the mixing conditions.

The tests of the GOLD 08 and the Compact unit met the uncertainty criterion given in EN 308. However, the test of the old PM Luft GOLD 3-4-3 unit showed an uncertainty higher than this criterion due to incomplete mixing of the tracer gas in the exhaust air duct. This unit is installed in a ventilation system in operation, and no action could be taken to decrease the uncertainty. Despite the uncertainty, it is concluded that this old unit met a requirement of maximum 3% carry-over. The two newer units showed a carry-over of less than 0.5%.

Method

The tests were conducted in accordance with instructions for carry-over tests specified in the standard EN 308:1997.

Tracer-gas experiments

Dinitrogen oxide was used as tracer-gas. The gas was measured using a calibrated instrument of the brand Brüel and Kjaer, type 1302 (serial number 1566626). The instrument is based on the principle of photo acoustic spectroscopy. According to the manufacturer the lowest detectable concentration is 0.03 ppm and the output signal in linear at least up to 300 ppm.

The tracer gas was supplied from a gas tank via a regulator and a precision rotameter. The gas flow was adjusted using a needle valve. To generate low gas flow rates (up to 3 l/min) a rotameter of the model Porter – B-125-50 "Ruby float" was used. Higher gas flow rates (up to 12 l/min) were generated using a rotameter of the model Porter B-250-8 "Steel float".

In all three tests the tracer gas was injected into the exhaust air duct, far upstream of the tested unit. The exhaust air concentration was measured close to the tested unit. Both the exhaust air concentrations and the supply air concentrations were measured in multiple points over the duct cross section. Any observed variations of the concentration over the duct cross section are reported below.

The carry-over was calculated as the ratio supply air concentration to exhaust air concentration, and presented as the percentage carry-over relative to the supply air flow rate.

Pressure differentials and airflow rates
The static pressure differential between supply and exhaust air was measured using a calibrated (2011-04-15) micro-manometer of the brand DPM, model TT 470S. The measurement points were located close to the rotary heat exchanger in locations 11 and 22, as indicated in Figure 1.

The supply and exhaust air flow rates were measured using the surveillance systems integrated in the test-rig and in the air handling systems where the tested units were installed:

Test-rig
The supply airflow rate in the GOLD 08 unit was determined by pressure differential measurements over an orifice designed in accordance with the standard ISO 5167. The exhaust airflow rate was measured using a conical air inlet designed according to the standard BS 848-Part 1: 1980. The pressure differential sensors were calibrated 2011-04-15.

Air handling systems
The air flow rates in the Compact unit and the PM Luft unit were determined by measurement of the pressure differential between the suction chamber and the narrowest part of the fan inlet. The method is denoted Method A5 in the Swedish guideline "T22:1998 - Metoder för mätning av luftflöden i ventilationsinstallationer" (Methods for measurement of airflow rates in ventilation systems).

Uncertainties
The uncertainty of concentration measurements is about ±0.03 ppm - which is of the same magnitude as the concentration detection limit. The resulting uncertainty of the determined carry-over percentage is evaluated below - in connection with the reporting of results.

The uncertainty of the micro-manometer for measurement of pressure differential between supply and exhaust air is ±(1% of reading+0.2) Pa. Since the measured pressure differentials were in the range 9-13 Pa, the uncertainty can be estimated not to exceed ±3%.

The uncertainty of the measured airflow rates is estimated not to exceed ±5% for the GOLD 08 test conducted in the test-rig, and ±7% for the Compact Unit. The pressure sensor in the PM Luft/Gold-3-4-3 unit has not been calibrated since the unit was new – 15 years ago. Thus, the uncertainty of the airflow measurements in this unit has not been estimated.

Tested objects

Below, each of the three tested objects are described briefly. Figure 1 illustrates the position of the fans in relation to the heat recovery unit. All three units follow this principle.

GOLD 08 installed in test rig

The tested object is a new rotary heat exchanger. During the tests this unit was installed in the test-rig at SWEGON Test Center. The unit is intended for airflow rates between 0.2 and 1.0 m^3/s. The test was carried out at a supply airflow rate of 0.73 m^3/s.

Compact unit

The tested object is a part of an air handling unit (TA/FA 56) in operation. Thus, the test shall be considered as a field test rather than a laboratory test. The Compact Unit, including the rotary heat exchanger was manufactured in 2007 and installed at the site in 2008. The unit is intended for airflow rates between 0.08 and 0.260 m^3/s. The test was carried out at a supply airflow rate of 0.14 m^3/s.

PM Luft/GOLD 3-4-3

The tested object is a part of an air handling unit (TA/FA 22) in operation. Thus, also this test shall be considered as a field test rather than a laboratory test. The GOLD 3-4-3 unit, including its rotary heat exchanger, was manufactured and installed about mid nineties. So, it is an old unit which has been in operation for about 15 years. The test was carried out at a supply airflow rate of 1.22 m^3/s.

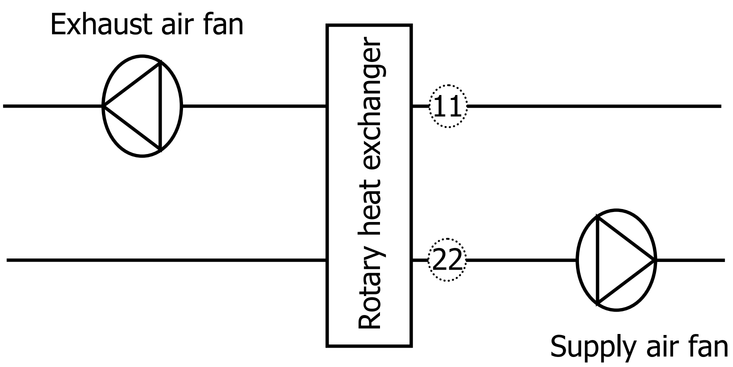

Figure 1. Location of fans relative to the rotary heat exchanger. The numbers 11 and 22 indicates the "exhaust air in" and "supply air out" locations.

Results

The measured tracer gas concentrations are shown in Table 1. In all three tests the background concentration in the supply air was measured both before and after tracer gas was released in the exhaust air. As the table shows, this background concentration was close to 0.7 ppm in all cases.

For each experiment the table shows the average value of the exhaust air and supply air concentrations measured. In addition, the lowest and the highest concentration values are presented.

Table 1. Measured tracer gas concentrations.

Unit	Back-ground *(ppm)*	Exhaust air concentration *(ppm)*			Supply air concentration *(ppm)*		
		Average	Mini-mum	Maxi-mum	Average	Mini-mum	Maxi-mum
GOLD 08 installed in test-rig	0.69	267	247	279	1.76	1.71	1.8
Compact Unit	0.77	317	305	323	1.75	1.50	2.15
PM Luft/GOLD-3-4-3	0.75	157	146	167	3.11	1.99	4.48

Carry-over

The carry-over values shown in Table 2 have been calculated according to the following:

Carry-over $= a_{22}/a_{11}$

a_{22} *= supply air conc. – background conc.*

a_{11} *=exhaust air conc. – background conc.*

- The average carry-over values are calculated using the average a_{11} and a_{22} concentration values,.
- The minimum carry-over values are calculated using the minimum a_{22} value and the maximum a_{11} value.
- The maximum carry-over values are calculated using the maximum a22 value and the minimum a11 value.

Table 2. Carry-over values calculated from the concentration measurements presented in Table 1.

Unit ID	**Description**	**Carry-over** *Average*	**Carry-over** *Minimum*	**Carry-over** *Maximum*
GOLD 08 installed in test-rig	New rotary heat exchanger	a_{11}=266 ppm a_{22}=1.07 ppm Carry-over=0.40%	a_{11}=278 ppm a_{22}=1.02 ppm Carry-over=0.36%	a_{11}=246 ppm a_{22}=1.11 ppm Carry-over=0.45 %
Compact Unit	Unit in operation since 2008	a_{11}=316 ppm a_{22}=0.98 ppm Carry-over=0.31%	a_{11}=322 ppm a_{22}=0.73 ppm Carry-over=0.23%	a_{11}=304 ppm a_{22}=1.38 ppm Carry-over=0.45 %
PM Luft/GOLD-3-4-3	Unit in operation since mid nineties	a_{11}=156 ppm a_{22}=2.36 ppm Carry-over=1.5%	a_{11}=166 ppm a_{22}=1.24 ppm Carry-over=0.8%	a_{11}=145 ppm a_{22}=3.73 ppm Carry-over=2,6 %

Uncertainty
In Table 3 the average concentrations a_{11} and a_{22} are presented together with a concentration range that covers the variations observed at each measurement location, see Table 2. These concentration variations - over the cross section of each measurement location - are substantially larger than the uncertainty related to the precision of the gas analyzer (±0.03 ppm). Thus, the uncertainty of the measurement is mainly due to the tracer gas not being perfectly mixed with the air. The calculated carry-over values are also presented in Table 3, together with their estimated uncertainties.

The relative uncertainty of the carry-over values has been estimated as the square root of the sum of the squares of the relative concentration variations in exhaust and supply air. As shown in Table 3, the uncertainty of the carry-over values meets the requirement according to the standard EN 308, both for the GOLD 08 and the Compact Unit. However, the uncertainty requirement is not met for the PM Luft /GOLD-3-4-3 unit. This is explained by the fact that this unit is a field installation, where tracer gas mixing is hard, or even impossible to obtain.

Table 3. Result of uncertainty calculation.

Unit ID	**Description**	**a_{11}** *exhaust*	**a_{22}** *supply*	**Carry-over**	**EN 308 uncertainty require-ment**
GOLD 08 installed in test-rig	New rotary heat exchanger	266 ± 20 ppm (±7.5% rel.)	1.07 ± 0.05 ppm (±4.7% rel.)	0.40%±0.04% (±9% relative)	±25% relative
Compact Unit	Unit in operation since 2008	316 ± 12 ppm (±3.8% rel.)	0.98 ± 0.40 ppm (±41% rel.)	0.31%±0.13% (±41% rel.)	±50% relative
PM Luft/GOLD-3-4-3	Unit in operation since mid nineties	157 ± 11 ppm (±7.1% rel.)	2.36 ± 1.37 ppm (±58% rel.)	1.50±0.88% (±59% rel.)	±25% relative

Sensitivity of the method
According to EN308 the injection rate of the tracer gas shall be sufficient to allow determination of a carry-over value of 0.1%. The supply air concentration, a22, which would correspond to a carry-over value of 0.1%, has been calculated for each unit, given the measured exhaust air concentrations presented in Table 3:

Unit	**a_{22}** (above background conc.)
GOLD 08	0.27 ppm
Compact Unit	0.32 ppm
PM Luft/GOLD-3-4-3	0.16 ppm

The a_{22} values listed above are five to ten times the detection limit of the gas analyzer used. Thus, the measurements are judged to have sensitivity sufficient to determine carry-over values down to 0.1%.

Conclusions

The results of the tests are summarized in Table 4. It can be concluded that both the GOLD 08 and the Compact Unit have carry-over values below 0.45%. The PM Luft/GOLD-3-4-3 unit has a carry-over value below 2.6%. These are maximum carry-over values where the uncertainty is accounted for.

Table 4. Summary of test results.

Unit ID	**Description**	**Supply /exhaust airflow rate**	**Supply – exh. static pressure difference**	**Carry-over** (percent of the supply airflow rate)
GOLD 08 installed in test-rig	New rotary heat exchanger	0.87 / 0.88 *(kg/s)*	13 ±5*Pa*	0.36 – 0.45 *%*
Compact Unit	Unit in operation since 2008	0.17 / 0.13 (kg/s)	12 ±2*Pa*	0.23 – 0.45 *%*
PM Luft/GOLD-3-4-3	Unit in operation since mid nineties	1.46 / 1.32 (kg/s)	9 ±3*Pa*	0.8 – 2,6 *%*

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