Odour emission from broiler production

Test report

Document information

Document title	Test report VERA Odour emission
Project	VERA_broilers_odour
Responsible	Martin Nørregaard Hansen, SEGES
Version	1-1
Status	Submitted to ETA-Danmark

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1 INTRODUCTION

This test was performed to quantify the odour emission from broiler houses. The broiler house system is described in detail in section 4.1.

1.1 Verification protocol reference

This test was performed according the test requirements defined in the VERA Test Protocol for Livestock Housing and Management Systems, version 1 2011-29-08 (VERA, 2011)

2 CONTACT DATA

2.1 Name and contact address of the customer

The test was performed and funded by the Danish Fjerkræafgiftsfond (the poultry levy fond). Contact: Natasja Jelskov Fjerkræafgiftsfondens Fondssekretariat, Phone +45 3339 4042. E-mail fjerkraeafgiftsfonden@lf.dk, www.fjerkraeafgiftsfonden.dk

2.2 Names and addresses of the test farms

Names and addresses of test farms can be seen in Table 1. Page 3.

2.3 Name and contact address of the test organisation

The test was performed by the Technological Institute, AgroTech (TI-AgroTech), Agro Food Park 15, DK-8200 Aarhus N, Denmark in cooperation with SEGES.

2.3.1 Test responsible

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2.3.4 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:

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3 BACKGROUND AND AIM

The annual broiler production is in Denmark close to 100 mio. The production level is relatively constant; however, the production takes place at fewer and bigger production units. The main part of the production takes place at about 225 larger farms, situated mainly in the peninsula Jutland. The high number of broilers produced at the individual farms cause local odour emission, which may cause odour nuisance when farms are situated close to neighbors and villages.

Broiler production is, like other Danish husbandry production systems, regulated by an Environmental Approval Act for Livestock Holdings. The approval act gives the frame for approval of projects for livestock holdings, and has a national minimum requirement for environmental protection for odour, ammonia, nitrates, and phosphorus surplus. The odour impact of broiler production is therefore part of the environmental approval act involved in planning of new or enlarged production systems. However, to estimate the odour impact of the broiler production facilities the actual odour emission from the broiler production needs to be known. The aim of this project is therefore to quantify the odour emission from broiler housing units.

The odour emission from broiler housing units is expected to be influenced by temperature, and the density and mass of broilers. A Swedish study found that the odour emission from laying hens increased significantly with temperature (Nimmermark and Gustafsson, 2005). A high odour emission can therefore be expected when temperatures are high during the summer period. Due that the odour sampling periods were performed in the summer period when temperatures were higher than 16°C.

It is well established that odour emissions varies between farms (Zhou and Zhang, 2003). To obtain the average odour emission, it was decided to measure the odour emission repeatedly at several farms according the test requirement of the test protocol (VERA, 2011).

To ensure a sufficient test level, the odour emission measurements were executed in accordance to the prescriptions of the VERA test protocol for Livestock Housing and Management Systems version 2 (2011-29-08) requiring that the odour emission to be measured at four farms (VERA, 2011).

The scope of the test is to quantify the odour emission at four typical Danish broiler farms.

The odour emission has previously been measured at two broiler houses in a previous VERA test study (pre-test), these data were combined with the measurements taking place at two additional broiler houses in this study.

4 TEST PROCEDURE

4.1 Test sites

The test took place at four commercial broiler farms. All farms have conventional broiler production in housing systems typical for broiler production. At each farm one housing unit was chosen as test unit. Each test unit was approximately 100 m long and 20 m wide with a capacity for housing between 30,000 and 40,000 broilers. The actual number and size of broiler were measured and reported for each measuring period.

Farm 1

Farm 2

Farm 3

Farm 4

Figure 1. Arial view of the test farms involved in the study. The sections involved in the study is denoted X.

At all test farms the broiler production took place as an all-in, all-out production. At the end of a production cycle, all manure was removed before the housing system was cleaned, disinfected, and dried. Thereafter the sections were littered by sawdust and heated to 34˚C before newly hatched chickens were introduced to the housing system. No manure was taken out during the production cycle, and no further litter was added during the production cycle.

The heating of the test houses was performed by use of natural gas burners and straw heated calorifiers (Table 1).

The test sections were equipped with traditional negative pressure ventilation system. The air exchange was controlled by either SKOV DOL 92A or SKOV DOL 539 climate and production computer system. Both systems provide a precise regulation and registration of the ventilation and climate control of the production test sections.

4.2 Characteristics of the test farms

The characteristics of the test farms can be seen in Table 1.

Table 1. Key characteristics of test farms.

	TEST SITE CHARACTERISTICS			
Parameter	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4**
Farm owner	Rokkedahl Landbrug	Rokkedahl Landbrug	A/S Dansk Landbrug	Karlslyst I/S
Address	Løgstørvej 113, 9600, Haubro, Aars	Nymøllevej 161, Kø-lby 9240 Nibe	Kongsvad Møllevej 6 9500 Hobro	Hobro Landevej 94 8830 Tjele
Contact Info	Else Olesen, phone: +45 2272 4650	Laurits Rokkedahl, phone: +45 4036 6351	Leif Barsballe Phone: +45 98544325	Bo Wieck-Hansen Phone: +45 29294999
CHR no.	71589	71589	18132	29077
House id			6	2
Number of broilers per test unit	31.000	37.000	36.000	37.800
Weight range (g) broilers	Newly hatch chickens (45 g) - 30/35 days old (ca. 2000 - 2150g)			
Bedding material	Sawdust, wood shavings and sphagnum (25 g/head)			
Space of test unit	1.500 m^2	1.812 m^2	1.698 m^2	1.967 m^2
Floor system	Solid floor covered with litter			
Manure removal system	The litter mat was removed at the end of each production cycle			
Feed composition	Wheat, proteins (soya), essential amino acids, minerals and vitamins			
Feeding system	Automatic dry food feeding system			
Feed analysis	Table of contents			
Ventilation	Mechanical negative pressure ventilation system (SKOV, DOL 92A)	Mechanical negative pressure ventilation system (SKOV DOL 539)	Mechanical negative pressure ventilation system (SKOV DOL 539)	Mechanical negative pressure ventilation system (SKOV DOL 539)
Ventilation capacity (max)	Roof ventila-tion:12x18.800=165.600 m^3 h^{-1} Gable fans: 2 x 40.300 m^3 h^{-1}	Roof ventila-tion:13x14.000=182.000 m^3 h^{-1} Gable fans: 2 x 40.300 m^3 h^{-1}	Roof ventila-tion:15x12.400=186.000 m^3 h^{-1} Gable fans: 2 x 35.000 m^3 h^{-1}	Roof ventila-tion:15x12.400=186.000 m^3 h^{-1} Gable fans: 2 x 35.000 m^3 h^{-1}
Heating system	In-house natural gas burner and Water based calorifiers, heated by straw Incineration	Water based calorifiers, heated by straw Incineration	Water based finned walltubes, heated by straw Incineration	Water based walltubes, heated by straw Incineration

4.3 Integration of pre-test results

The odour emission of two of the test farms (test farm 1 and 2) was measured in a previous VERA test of the technology effects of a heat exchange system. This study was performed in the period between June 2014 and August 2015. The pre-test was performed by test methods that fulfilled the requirements of the VERA protocol (VERA, 2011). In the present study only results of the control sections of the pre-test are included. The method used and the results of the pre-test are described in detail in Hansen et al. (2014). However, a brief description will be included in the following.

The pre-test involved nine odour measurements periods at two commercial broiler farms (see farm 1 and 2 in Table 1). Of the nine measurement periods five were performed in the last part of the production cycle, three in the medium, and one in the initial part of the production cycle. Odour results of test periods performed at out-door temperatures higher than 16°C were integrated as pre-tested measurements data.

As the pre-test was performed in accordance to the requirement of the VERA test protocol, the odour sampling results of two of the requested four test farms was covered by the pre-test. These results are integrated into this test report. The number of measuring events requested and completed in the pre-test, and the remaining number of measurement events at the two additional test farms can be seen in table 2.

Table 2. Number of requested measurement days, number of measurement days completed in pre-test, and required additional measurements days at test farm 3 and 4.

	Requested by the protocol			Completed in pre-test			Additional measurements		
Broilers production cycle	Farm 1	Farm 2	In total	Farm 1	Farm 2	In total	Farm 3	Farm 4	In total
Initial (0-10 days)	1	1	2	1	1	2	1	1	2
Medium (11-21 days)	3	3	6	3	3	6	3	3	6
Last (22-slaughter day)	5	5	10	5	5	10	5	5	10
Total	9	9	18	9	9	18	9	9	18

4.4 Test progress

The progress of the test and the measurements taking place at test farm 3 and 4 can be seen in Table 3.

Table 3. Test progress for the test and the measurements related to test farm 3 and 4. The specific measuring dates depended on the specific day of introduction of broilers, that out-doors temperatures could be expected to be higher than 16 °C, and the age of the broilers.

Year	2018												2019								
Task/month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug.	Sep	oct	Nov	Dec.	Jan.	Feb.	Mar	Apr	May	Jun	jul	Aug	Sep
Test plan	X	X	X	X																	
Acceptance of test plan			X	X																	
Installation and pre-testing				X	X																
Start test period					X																
Odour sampling periods farm 3						XXXX	XX														
Odour sampling periods farm 4					XX	XXXX															
End of test period								X													
Data inventory									X	X											
Test report draft										X											
Test report quality assurance											X										
Test report final version												X									

Table 4. List of measuring dates.

Sampling period	Farm 1 (pre-test)	Farm 2 (pre-test)	Farm 3	Farm 4
1	11.09-2014	20.08-2014	18.06-2018	28.05-2018
2	10.12-2014 [a]	11.09-2014	20.06-2018	31.05-2018
3	02.02-2015 [a]	09.10-2014	25.06-2018	05.06-2018
4	19.03-2015 [a]	04.12-2014 [a]	28.06-2018	06.06-2018
5	03.09-2015 [a]	24.02-2015 [a]	02.07-2018	12.06-2018
6	16.06-2015 [a]	07.05-2015 [a]	03.07-2018	13.08-2013
7	21.07-2015	20.05-2015 [a]		
8	29.07-2015	12.08-2015		
9	03.09-2015	20.08-2015		

[a] Results not included due out-door temperatures lower than 16 °C

4.5 Test design and sampling methods

4.5.1 Analytical parameters

Odour was the primary performance test parameters. In addition, a number of operational parameters were measured throughout the test period. A list of the parameters can be seen in Table 5.

Table 5. Test parameters and involved analytic methods and detection limits

Parameter	Analytical method	Limit of detection	Uncertainty
Odour	Olfactometric analyses, EN 13725/AC:2003	100 OU_E/m^3	---
Air Temperature	Testo 174H	0.1 °C	+/- 0,5 °C
Relative air humidity	Testo 174H	0.1 %	+/- 3 %RH °C
Wind direction (°) and speed (m/s)	UTM based climatic data service developed by the Danish Meteorological Institute (DMI)		

In addition to the parameters listed in Table 5, several additional operational parameters were recorded throughout the test period. The additional operational parameters include number of dead broilers, on/off periods of use of gable ventilators, air temperature and humidity, and the daily consumption of feed and water. The additional operational parameters were recorded daily and electronically logged at the production computer (Appendix 1).

The overall principle for quantification of odour emission from housing systems is to quantify the odour concentration in air leaving the housing system, and the volume of air leaving the housing system. As broilers are housed in mechanically ventilated housing systems, the emissions were quantified by simultaneous on-line measurements of air exchange and determination of the odour concentrations in the air leaving the housing system.

4.5.2 Air flow measurement

Emission measurements from livestock housing systems require measurement of the air exchange (ventilation) of the housing systems.

The ventilation rate gives the volume flow of air drawn out of the animal house. The direct techniques for measuring airflow involve measurements or estimation of airflow capacity of the farm exhaust air by use of supplying air fans (anemometers) or by use of CO_2 balance method (CO_2 balance method). The two methods are briefly described in the following.

The airflow of the test houses was continuously computed based on the manufactured specified fan performance curve for the specific ventilation installation, however, such calculation can introduce error due to altered fan curve arising from uncontrollable variables; such as loose fan belt, partially open and dirty shutters, and dirty fan blades. Due that, the direct measurement method is preferred. The direct method involves use of portable fan wheel anemometers calibrated in situ to reflect the actual operating conditions. However, use of portable fans in broiler houses are challenges by the high number of air outlets (13-14 per house) and the use of both on/off and stepless regulated ventilation ducts (multistep ventilation systems).

Broiler housing in Denmark are often equipped with multistep ventilation systems. This is a ventilation principle based on under-pressure, where the number of operating fans is regulated based on the air exchange requirement. The system involves fans that are stepless regulated and fans that are on-off regulated. The stepless fans are computer regulated to produce between 10 to 100 % of their maximal air flow capacity, while the on-off fans are activated only when required by the controlling computer. Each time an extra on-off fan is activated, the air flow of the adjoining stepless fan is reduced from 100 to 10 %. A modern broiler house is often equipped with 1 or 2 stepless fans and 10-13 on-off fans, depending on the size of the building and the ventilation brand.

In addition, most broiler houses have large gable fans, that can be activated as a supplement to the ridge ventilation fans. These are normally only activated when external temperatures are high, and in the last part of the production cycle when the heat production of broilers is at the highest. Gable fans are on-off regulated.

The measurement of air flow by use direct continuous measurements (anemometers) is challenging in broiler houses due the high number of air outlets and the use of both on-off and stepless regulated ventilation outlets (Xin et al., 2009). The challenge is further increased by the fact that the controlling computer puts in different numbers and groups of on-off fans depending on the air exchange requirement.

The used method for calculating the air exchange in test farm 3 and 4 will therefore be described in the following. The method used for calculation of the air exchange for test farms 1 and 2, can be seen in Appendix 3. Test report, test farm 1 and 2.

Test farm 3 and 4 were identical regarding their ventilation system. Both test houses were equipped with one stepless fan (SKOV, type ZA ECT 632-6), 14 on-off fans (SKOV, type ZA DCT 632-6) and two gable fans (SKOV, type DB 1400 400v).

Prior to the start of the test, the stepless fans in both test farms were equipped with SKOV Dynamic Air Flow measuring system. The dynamic air systems were coupled to the computer system controlling the ventilation system to allow registration of the actual air flow during the test sampling periods.

The air exchange was in both test houses controlled by an SKOV DOL 53x system that regulates the air flow mainly depending on the temperatures and the in-house CO_2 concentration. The DOL system registered the actual number of fans in use, and the air exchange of the stepless fans.

The air exchange through the on-off fans was calculated based on the number in use and the measured in-house under-pressure (Pascal). The actual air exchange at the measured under-pressure was calculated by use of calibrations schemes provided by the producer of the fans. An example of the calibrations scheme can be seen in Table 6.

Table 6. Correlation between in-house under-pressure and the air flow through different types of SKOV ridge on-off fans. The test houses were equipped with the DCT 632-6 on-off fans.

Ventilatortype	409143 ECT 632-6	409146 ECT 632-6 CSA	409144 DCT 632-6
Ventilatorydelse			
Omdrejninger [pr. minut] (mærke)	890	1040	930
Luftydelse [m^3/h] (ved –10 Pa)	12.700	14.900	13.100
Luftydelse [m^3/h] (ved –20 Pa)	12.200	14.500	12.700
Luftydelse [m^3/h] (ved –30 Pa)	11.700	13.900	12.100
Luftydelse [m^3/h] (ved –40 Pa)	10.800	13.300	11.500
Luftydelse [m^3/h] (ved –50 Pa)	9.800	12.500	10.600
Luftydelse [m^3/h] (ved –60 Pa)	7.200	11.800	9.300

To ensure that the provided calibration schemes gives a correct correlation between the in-house under-pressure and air flow, an onsite test was performed after the end of the test periods. The used methodology and the results found can be seen in Appendix 2. On site test of air flow through on-off fans.

Based on the actual number of ventilation fans in use, the measured in-house under-pressure, and the Dynamic Air measurements of the air exchange by the step less fans, the total air exchange during the measurement periods were calculated (Table 7).

Table 7. Calculation of the total air exchange during the different test periods at test farms 3 and 4. The total air exchange is the sum of the air exchange taking place from the stepless, the ridge on-off and the gable on-off fans in use.

Test period	Measured in-house under-pressure, Pascal	Air flow step-less ventilator, m^3 h^{-1}	Ridge on-off fans in use, N	Air flow per ridge on/off fan, m^3 h^{-1}	Gable on-off fans in use, N	Air flow per gable fan, m^3 h^{-1}	Total air flow, m^3 h^{-1}
Test farm 4							
1	12	6,311	6	13,020			84,431
2	18	192	11	12,780			140,772
3	16	2,071	14	12,860			182,111
4	24	12,515	12	12,460	2	38,480	238,995
5	12	12,844	14	13,020	2	40,820	276,764
6	6	11,788	14	13,100	2	41,000	277,188
Test farm 3							
1	2	6,667	3	13,100			45,967
2	4	6,161	5	13,100			71,661
3	12	8,244	14	13,020	2	40,820	272,164
4	12	8,275	14	13,020	2	40,820	272,195
5	8	8,280	14	13,100	2	41,000	273,680
6	16	8,465	14	12,860	2	40,460	269,425

4.6 Determination of odour emission

The principle for determination of odour emission is sampling of odorous air from air exhausts. The odorous air was drawn from the air exhausts and sampled in 30 l nalophan bags. The odour bags were filled by use of vacuum containers. The odour concentration of the sampled air was subsequently quantified by dilution olfactometric within 24 hours after sampling.

Each measurement day three odour samples were simultaneously sampled at each test farm.

The used odour sampling system is mobile. Once at the site, the vacuum containers were prepared and connected to diaphragm pumps that allowed a controlled airflow from the vacuum containers. The vacuum was regulated so that the odour sampling time was 30 minutes per sample. Marked odour bags were inserted into the vacuum containers, and the inlet of the bags were connected to the measuring point by a Teflon tube.

Before test sampling, the odour bags were conditioned by filling the bags with air from the sampling point and afterwards emptying the bags. After test sampling the odour samples were kept away from direct sun- and daylight, as light or heating may enhance the chemical changes of the samples. The filled odour bags were stored and transported in closed cardboard boxes.

The sampled odour samples were as soon as possible after sampling transported to an accredited odour laboratory, where analyses took place before 24 hours after the sampling event.

The total odour emission was calculated by the following equation

$$\boldsymbol{E_{T_j}} = \overline{\boldsymbol{OU_{EJ}}} * \left(\boldsymbol{V_j}\right)$$

Where
E_T = Total odour emission, Odour Units (OU_E) house^{-1} hour^{-1}
OU_E = Mean odour unit, OU_E m^{-3} air
V_j = Air exchange in test section, m^3 air h^{-1}
j = Actual measurement period.

The odour emission per broiler was calculated by the following equation

$$\boldsymbol{E}_{OU_{E_j}} = \frac{\boldsymbol{24}}{\boldsymbol{N_j}} * \ \boldsymbol{E_{T_j}}$$

Where

$\boldsymbol{E_{OU_E}}$ = *Odour emission per head and day, Odour Units (OU_E) head^{-1} day^{-1}*

N = Total number of broilers in test section

j = Actual measurement period

The odour emission per 1000 kg body mass was calculated by the following equation

$$\boldsymbol{E}_{\boldsymbol{OU}_{1000_j}} = \frac{1000}{N_{j \times \overline{M_J}}} * \ \boldsymbol{E_{T_j}}$$

Where

$E_{OU\ 1000}$ = Odour emission per 1000 kg broilers, Odour Units (OU_E) 1000 kg broiler^{-1} hour^{-1}

$\overline{M_J}$ = Mean weight of broilers at the measurement day, kg broiler^{-1}

The odour emission per m^2 barn area was calculated by the following equation.

$$E_{area_j} = \frac{E_{T_j}}{A_i}$$

Where

E_{area} = Odour emission per m^2 barn area, Odour Units (OU_E) m^{-2} $hour^{-1}$

A = Total barn area, m^2

i = actual test farm.

4.7 Analytical laboratory

Odour samples were analysed by dynamic dilution olfactometric analyses. The analyses were performed by the accredited external odour analytical (Danish Meat Research Institute), at the Technological Institute, Tåstrup, Dk.

4.8 Preservation and storage of samples

Odour samples

Odour samples were sampled and stored during transport according the description given by Miljøstyrelsen (2006) regarding sampling and analyses of odour samples from livestock production units.

5 DATA MANAGEMENT

Data management including filling and archiving procedures are described in the TI-AgroTech Test Centre Quality Manual (AgroTech, 2009).

5.1 Data storage, transfer and control

Relevant broiler production, ventilation, and housing data were electronically and manually collected by the farm responsible. These data were automatically logged at the climatic controlling computer at the test sites. These data were on-line retrieved at the specific time of sampling. An example can be seen in appendix 1. Other data were collected by electronic means at the test site and sent via internet to a PC in the TI-AgroTech main office.

Results from external laboratories were sent electronically by email and by a paper version by mail. A list of data compilation and storage can be seen in table 8.

Table 8. Data compilation and storage summary.

Data type	Data media	Data recorder	Recording of data	Data storage
Test plan and test report	Protected pdf-files.	Test responsible	When approved	Files and archives at SEGES
Data manually recorded at test site	Data recording forms	Test staff at test site	During collection	Files and archives at TI-AgroTech
Calculations	Excel files	Test responsible	After conclusion of data sampling	Files and archives at SEGES
Analytical reports	Paper / pdf-files	Test responsible	When received	Files and archives at SEGES

5.2 Statistical data processing method

The odour emission was calculated for the individual test locations and averaged for all farm locations.

The mean and the median odour emission were calculated for the individual test farms, before averaged for all test farms.

6 QUALITY ASSURANCE

The test was performed according the TI-AgroTech Test Centre Quality Manual, which is ISO 9001 certified (AgroTech, 2009).

6.1 Test system control

The stability of the test equipment was controlled by supervision and recording of data. Procedures for ensuring that test facilities and equipment were calibrated and fit for the purposes are described in the Quality Manual for the Laboratories of TI-AgroTech (AgroTech, 2009). These procedures are subject to internal audits from the TI-AgroTech Management.

6.2 Data integrity check procedures

All transfers of data from printed media to digital form and between digital media are checked by spot check undertaken by the test responsible. If errors were found in the spot check, all data transfers from the specific data collection were checked.

6.3 Test system audits

Internal audits were done following the procedure described in the TI-AgroTech Test Centre Quality Manual.

6.4 Farm maintenance

The farm owners were responsible for maintenance and repair of the ventilation, housing, and production system. If the farm owner identified a maintenance problem, that could not be solved by the farmer, the problem was recorded and reported to the test institute.

Irregularities and break downs during the test period were recorded and informed to the test institute by the farm owner together with information about the cause of the breakdown, the length of the down period, and how the problem was solved.

6.5 Health, safety and wastes

The project did not imply any health, safety or waste issues.

7 TEST REPORT

The test report was prepared in accordance to the requirement listed in the VERA protocol (VERA, 2011). The test report compiling the results of test farm 1 and 2 can be seen in appendix 3.

7.1 Test report review

The test report was reviewed by the appointed technical expert Arne G Hansen.

7.2 Deviation to the test protocol

A few deviations to the test protocol were requested. These are listed in the following.

1. Determination of ammonia emission. Ammonia is one of the primary performance test parameters of the test protocol; however, as the ammonia emission from broiler houses has been previously measured and documented in a national study (Hansen MN., 2016), the ammonia emission was not measured in the this study.

2. Determination of dust emission. Dust is another primary performance test parameters of the test protocol; however, according the test protocol, a test can be designed to test the primary target parameter of the technology e.g. an ammonia reducing technology, thereby omitting testing of the other primary parameters. However, this is only possible if it can be ensured that the technology in all probability does not have any negative effect on the non-tested parameters (VERA, 2011 page 6). As no technology was tested in this study, the dust emission was not measured.

3. Deviation of the distribution of sampling periods
   According pre-agreement with the Danish Melt experts and the Danish EPA, all sampling periods included took place during summer periods at out-door temperatures higher than 16 °C, and when the broilers were in the last part of the production cycle. This is a deviation to the distribution of the sampling periods suggested by the VERA protocol, which can be seen in Figure 2. According the test protocol, the test periods shall be evenly distributed over a full year, and during the production cycle.
   The reason for the agreed deviation is that odour emission mainly is a nuisance during the summer period, and that the highest odour emission is expected to be found in the last part of the production cycle, when the manure production and the air exchange is high due the high body mass of the broilers.

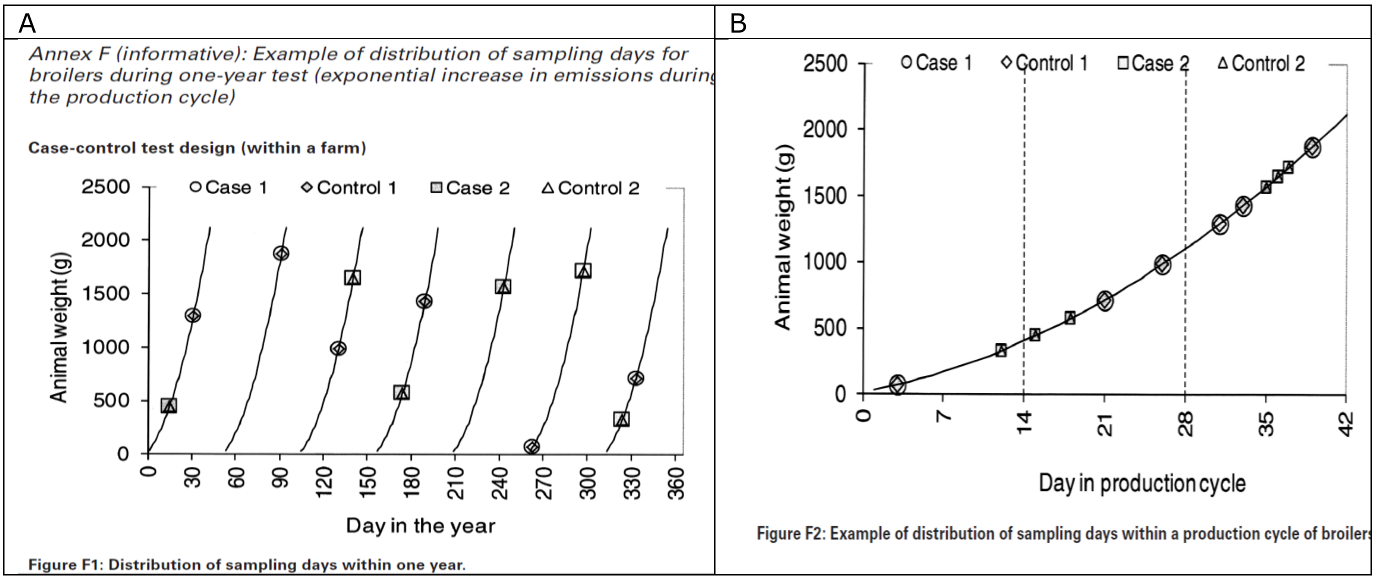

Figure 2. Suggested plan for distribution of samplings days copied from the VERA protocol (VERA, 2011). The suggested distribution of sampling days within one year is shown to the left (A), and the suggested distribution of sampling days within the production cycles can be seen to the right (B).

8 RESULTS

The results found at the individual test farms can be seen in Table 9, Table 10, Table 11, and Table 12. Considerable variation was observed between the different test periods.

Table 9. ***Test farm 1****. Samplings dates, conditional parameters and mean odour concentration and emission at test periods performed at test farm 1. Test periods that took place at temperatures lower than 16°C are excluded.*

Test period	*Sampling date, dd-mm-yyyy*	*No of broilers*	*Age of broilers, Days*	*Start measurement, hh:mm*	*Outdoor temperature °C*	*Indoor air temperature °C*	*Ventilation rate, $m^3\ h^{-1}$*	*Odour concentration, $OU_E\ m^{-3}$*	*Odour emission, OU_E head^{-1} s^{-1}*	*Odour emission, OU_E 1000kg^{-1} s^{-1}*
1	11-09-2014	30804	10	10:58	25.2	28.7	9,956	430	0.04	148
7	21-07-2015	26474	19	09:38	17.1	24.5	N.D.	1167	N.D.	N.D
8	29-07-2015	26339	27	09:15	16.9	23.4	52,910	1600	0.89	679
9	03-09-2015	27695	16	10:45	16.4	26.35	16,346	1533	0.25	456

Table 10. ***Test farm 2.*** *Samplings dates, conditional parameters and mean odour concentration and emission at test periods performed at test farm 2. Test periods that took place at temperatures lower than 16°C are excluded.*

Test period	*Sampling date, dd-mm-yyyy*	*No of broilers*	*Age of broilers, Days*	*Start measurement, hh:mm*	*Outdoor temperature °C*	*Indoor air temperature °C*	*Ventilation rate, $m^3\ h^{-1}$*	*Odour concentration, $OU_E\ m^{-3}$*	*Odour emission, OU_E head^{-1} s^{-1}*	*Odour emission, OU_E 1000kg^{-1} s^{-1}*
1	20-08-2014	37536	8	10:24	14.7	33.7	4,120	1020	0.03	139
2	11-09-2014	37177	30	14:47	23.5	24.2	173,212	357	0.46	274
3	09-10-2014	36084	16	10:00	16.0	27.12	17,334	997	0.13	235
8	12-08-2015	31765	20	10:00	17.2	25.8	36,846	1083	0.35	415
9	20-08-2015	31612	28	10:35	20.9	22.5	196,475	170	0.29	213

Table 11. ***Test farm 3.*** *Samplings dates, conditional parameters and mean odour concentration and emission at test periods performed at test farm 3.*

Test period	*Sampling date, dd-mm-yyyy*	*No of broilers*	*Age of broilers, Days*	*Start measurement, hh:mm*	*Outdoor temperature °C*	*Indoor air temperature °C*	*Ventilation rate, $m^3\ h^{-1}$*	*Odour concentration, $OU_E\ m^{-3}$*	*Odour emission, OU_E head^{-1} s^{-1}*	*Odour emission, OU_E 1000 kg^{-1} s^{-1}*
1	18-06-2018	35,347	19	14:15	17.1	26.7	45,967	797	0.29	387
2	20-06-2018	35,313	21	12:09	18.6	26.9	71,661	1150	0.65	729
3	25-06-2018	35,192	26	14:00	26.8	27.2	272,164	520	1.12	871
4	28-06-2018	35,099	29	10:26	27.1	27.3	272,195	490	1.06	703
5	02-07-2018	34,929	33	12:18	25.9	25.1	273,680	577	1.26	722
6	03-07-2018	34,846	34	10:16	21.8	23.2	269,425	470	1.01	580

Table 12. ***Test farm 4.*** *Samplings dates, conditional parameters and mean odour concentration and emission at test periods performed at test farm 4.*

Test period	*Sampling date, dd-mm-yyyy*	*No of broilers*	*Age of broilers, Days*	*Start measurement, hh:mm*	*Outdoor temperature °C*	*Indoor air temperature °C*	*Ventilation rate, $m^3\ h^{-1}$*	*Odour conc., $OU_E\ m^{-3}$*	*Odour emission, OU_E head^{-1} s^{-1}*	*Odour emission, OU_E 1000kg^{-1} s^{-1}*
1	28-05-2018	41,534	15	13:30	25.3	25.9	84,431	423	0.24	506
2	31-05-2018	41,482	18	10:22	25.1	25.9	140,772	243	0.23	372
3	05-06-2018	41,380	23	10:45	19.6	24.2	182,111	363	0.44	450
4	06-06-2018	41,363	24	10:00	27.5	24.5	238,995	380	0.61	574
5	12-06-2018	41,236	30	10:27	19.2	22.5	276,764	313	0.58	366
6	13-06-2018	41,214	31	10:00	16.2	21.8	277,188	400	0.75	455

Table 13 gives the average measured odour concentration and emission at the four test farms. Considerable variation was observed between the different test farms. The highest odour emission was observed from the two test farms involved in the study performed in 2018 (Test farm 3 and 4). The higher odour emission measured in 2018 may partly be explained by the unusual hot summer temperatures in 2018, which have caused higher ventilation requirement than normal summer condition.

Table 13. ***All test farms.*** *Average odour concentration and emission measured at the test farms.*

Test Farm	*No of broilers*	*Age of broilers, Days*	*Outdoor tempera-ture, °C*	*Indoor tempera-ture, °C*	*Ventila-tion rate, $m^3\ h^{-1}$*	*Odour conc., $OU_E\ m^{-3}$*	*Odour emission*		
							Per head OU_E head^{-1} s^{-1}	*Per 1000 kg OU_E 1000kg^{-1} s^{-1}*	*Per area $OU_E\ m^{-2}\ s^{-1}$*
1	27,828	18.0	18.9	25.8	28,433	1,183	0.39	428	7.0
2	34,835	20.4	18.5	24.4	85,597	725	0.25	255	4.8
3	35,121	27.0	22.9	26.1	200,849	667	0.90	666	16.0
4	41,368	23.5	22.2	24.1	200,044	354	0.48	454	10.0
Mean	**34,788**	**22.2**	**20.6**	**25.1**	**124,447**	**732**	**0.50**	**451**	**9.5**

The median and the mean odour emission given per head, per 1000 kg animals, and per m^2 of barn area can be seen in Table 14.

Table 14. ***All test farms.*** *Mean and median measured odour emission per head, per 1000 kg animals, and per m^2 of barn area. Mean values are given as mean ± 95% Confidence Interval (C.I.)*

Statistical parameter	*No. of sampling periods*	*Odour emission*		
		Per head OU_E head^{-1} s^{-1}	*Per 1000 kg OU_E 1000kg^{-1} s^{-1}*	*Per area $OU_E\ m^{-2}\ s^{-1}$*
Median	20	0.43	441	8.52
Mean ± 0.95% C.I.	20	0.50 ± 0.17	451 ± 97	9.45 ± 3.1

9 SUMMARY

The odour emission from broiler houses was studied by measuring the odour emission from four typical Danish forced ventilated houses each housing between 30,000 and 40,000 broilers. The study at each farm took place by six odour samplings campaigns, that predominantly took in the last part of the broiler production period, and at outdoor temperatures higher than 16 °C, when the odour emission is expected at the highest. The odour emission was measured by olfactometric analyses of odour concentration in out-let air sampled in ventilation pits and the correlated measured total air exchange rate of the test house. The average odour emission was found to be 0.5 OU_E per broiler per second, equal to 451 OU_E per 1000 kg broilers per second. The emission varied considerably, both between the different sampling campaigns and between the different farms.

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11 APPENDIX

LOG BOOK Production parameters

11.1 Appendix 1 – Logbook Productions and ventilation parameters

Example of the automatically registered information given by the SKOV climatic controlling computer DOL 53x

Test farm 4 Karlslyst 12/6-18 kl. 10:27		
Temperatur ventilationsluft	22,5 °C	
Temperatur ude	19,2 °C	
Relativ fugtighed ventilationsluft	65 %	
CO2	985 ppm	
Dag i rotation	29	
Foder/kylling ialt	2543 g	
Vand/kylling ialt	5331,56 g	
Vægt/kylling	1598 g	
Antal kyllinger	41236	
Ventilationsdata		
Multistep 1	On	
Multistep 2	On	
Multistep 3	On	
Multistep 4	On	
Multistep 5	On	
Multistep 6	On	
Trinløs ventilator %	100 %	
Spjældåbning	100,2%	
Trinløs ventilator m³/h	12844	
Ventilation af max	133,8 %	
Flow total	275836	
Undertryk	1,2mm H_2O	
Max ventilation		

11.2 Appendix 2. On site test of air flow through on-off fans

To ensure accordance between the air flow given by the ventilation schemes of the ridge on-off fans, and the actual air flow of on-off fans situated in the test houses, a test of the air flow of the on-off fans were performed after termination of the test periods.

Before the test one of the on-off fans was equipped by a SKOV Dynamic Air system to allow on-site measurement of the actual air flow at the specific condition in the test house. The SKOV Dynamic Air system is a measuring principle that constantly measures air performance in chimneys by use of a manometer system that measures the pressure difference between the livestock house and the exhaust unit.

During the test the ventilation of the broiler house was manually stepwise increased, while the influence on the in-house under-pressure and air flow through the on-off pit were registered. After the termination of the test, the measured air flow through the on-off pit was correlated to the in-house under-pressure and compared to the ventilation scheme given for the type of on-off fans used in the test house (see Table 6).

The test showed similar correlation between in-house under-pressure and air flow of the test and the ventilation schemes provided by the supplier of the on-off fans. The test also showed that the air flow rates found by the test were close to the values of the provided ventilation schemes (Figure 3).

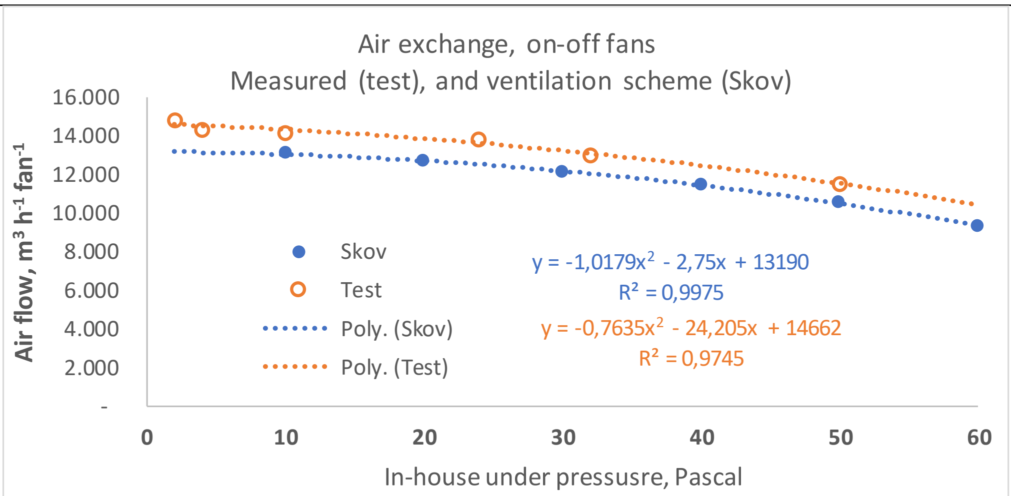

Figure 3. Correlation between in-house under-pressure and the air flow of the on-off fans in use. Results are shown for the on-site test (Test), and for the ventilation schemes provided by the supplier of the on-off fans (SKOV). The on-site test results were generated by use of a SKOV Dynamic Air flow measuring system attached to one of the on-off fans.

The test results show that the actual air flow of the on-off fans in the test houses during the test period can be estimated by measurement in-house under-pressure and the results of the ventilation schemes provided by the supplier of the fans.

11.3 Appendix 3. Test report, test farm 1 and 2

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AgroTech Taastrup
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AgroTech
Accelerate business

Odour and ammonia emission from broiler houses with and without a heat exchange system

Test report

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Accelerate business

Odour and ammonia emission from broiler houses with and without a heat exchange system

Test report

By Martin Nørregaard Hansen, AgroTech

Document information

Document title	Test report VERA Agro Clima Unit
Project	VERA_ACU_broilers
Responsible	Martin Nørregaard Hansen
Version	3
Status	Final

Table of contents

1 FOREWORD

This test was conducted to quantify the odour and ammonia effect of the Agro Clima Unit (ACU) Clima^{+} 200, type 2.5 when used as part of the ventilation and heating system in broiler houses. The ACU is developed by the company Agro Supply. The technology is described in detail in section 2.3.

The test was executed in accordance to the prescriptions of the VERA test protocol for Livestock Housing and Management Systems version 2 (2011-29-08) (VERA, 2011).

The test was planned, initiated, and organized in cooperation between the applicant, the involved farm managers, and the test institute AgroTech.

1.1 Contact addresses

1.1.1 The applicant

The applicant of the project was Rokkedahl Energi. The Contact person was Anja Møller Contact: E-mail: adm@rokkedahl-energi.dk. Phone: +45 30 28 72 10.

1.1.2 Test farms

The test took place at two commercial broiler farms. At each farm two identical broiler houses with room for approximately 30,000 broilers were chosen as test houses. The two test houses were alike, apart that one was equipped with an Agro Climate heat exchange unit (ACU) while the other was without the heat exchange system (control).

Table 1. Addresses and contact info of test farms.

	Farm 1	Farm 2
Address	Løgstørvej 113, 9600, Haubro, Aars	Nymøllevej 161, Kølby 9240 Nibe
Contact Info	Manager: Else Olesen, phone:+45 2272 4650 Owner: Mark Rokkedahl, Phone: +45 4036 6008	Manager: Michael Christensen, phone: +45 20411262 Owner: Mark Rokkedahl, Phone: +45 4036 6008

1.1.3 Test institute

The test was carried out by AgroTech, Agro Food Park 15, DK-8200 Aarhus N. AgroTech is an authorised technological service institute offering impartial consultancy and technological services.

1.1.4 Test responsible

Martin N. Hansen, Agro Food Park 15, DK-8200 Aarhus N, e-mail: mno@agrotech.dk, phone: +45 3092 1784.

1.1.5 Technical experts

The technical experts assigned to this test and responsible for review of test plan and test report includes:

Arne Grønkjær Hansen, AgroTech, Agro Food Park 15, DK-8200 Aarhus N. Phone: +45 4016 7713, E-mail: agh@agrotech.dk

Amparo G. Cortina, AgroTech, Agro Food Park 15, DK-8200 Aarhus N. Phone: +45 3091 0321, E-mail: aco@agrotech.dk.

Niels Provstgaard Agro Food Park 15, DK-8200 Aarhus N, e-mail: nipr@agrotech.dk , phone: +45 23305575.

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1.1.7 Technician

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1.1.8 Local adviser

Jens Elvstrøm, Videncenter for Landbrug. Phone: +45 4028 5535. Mail: jne@VFL.dk
(latter Søhøjlandets Regnskabskontor: +4587981689. Mail: je@shlrk.dk).

1.1.9 Intern revision

Niels Provstgaard, Agro Food Park 15, DK-8200 Aarhus N, e-mail: nipr@agrotech.dk, phone: +45 23305575.

1.1.10 Test period:

The test was initiated the 20th of August 2014 and ended the 3th of September 2015.

Signature and date (name, title, and name of institution in capital letters)

____ date______________
Senior Consultant Martin Nørregaard Hansen

AgroTech A/S, Institute of Agri Technology and Food Innovation, Agro Food Park 15, DK-8200 Aarhus N.

2 INTRODUCTION

This test report regards the verification of the heat exchange system (Agro Clima Unit (ACU) Clima$^+$ 200, type 2.5) developed by the company Agro Supply. The technology is described in detail in section 2.3.

2.1 Verification protocol reference

The test was performed according to the test requirements defined by the VERA Test Protocol for Livestock Housing and Management Systems, version 1 2011-29-08 (VERA, 2011)

2.2 Background and Aim

Most broilers are produced in mechanically ventilated broiler houses. The production takes place as an all-in, all-out production. Before the introduction of newly hatched broilers, the broiler houses are thoroughly cleaned, disinfected, dried, and littered. Prior to the introduction of newly hatched broilers, the temperature of the broiler houses has to be about 32-33°C. The temperature is gradually reduced to about 31°C after about a week and to about 20°C after three to four weeks. The heating of the broiler houses is normally provided by in-house gas burners and/or calorifiers heated by straw, oil or natural gas.

The high temperature requirement causes high energy cost. This can be reduced by use of heat exchange systems.

A heat exchange system is a thermal exchange system that recovers the thermal energy of air leaving a housing system to heat incoming air by a counter-current heat exchange system. The heat exchange system can be utilised to recover the thermal energy of the air drawn out from broiler houses to heat up the inflowing air and by that reduce the energy cost of heating. The use of a low cost heating system may influence the dryness of the broiler litter and thereby abate the emissions from broiler production. The aim of the study was to investigate to what extend the use of a heat exchange system effects the emission of ammonia and odour from broiler houses.

The Dutch company Agro Supply has developed an Agro Clima Unit (ACU) for broiler houses Figure 2. The ACU system reduces the energy requirement for heating broiler houses by means of counter current heat exchange system (Adamovský et al., 2008). However, the use of the ACU system may also influence the emission of ammonia from the broiler production as the inflowing ACU-heated air may reduce the in-house air moisture and thereby the moisture content of the broiler litter. A lower humidity of the broiler mat reduces the conversion of excreted uric acid into ammonia, and thereby the emission of ammonia from the broiler house (Liu et al., 2007).

The scope of the test was is to verify the environmental efficiency and operational stability of Agro Clima Unit (ACU) Clima$^+$ 200, type 2.5 for broiler production. The test is conducted in accordance to the test requirement described by the VERA test protocol for Livestock Housing and Management systems (VERA, 2011).

2.3 System description

2.3.1 Functional description of the ACU system

The technology evaluated was the Agro Clima Unit (ACU) Clima$^+$ 200, type 2.5 developed by the company Agro Supply (Figure 1).

Broiler production has a high energy requirement, especially in the first part of the production period caused by the high temperature requirement of newly hatched chickens. The in-house temperature in broiler houses follows a preset temperature schedule. The temperature of broiler houses therefore has to be regulated by heating. This heating can partly be provided by the use of a heat exchange system.

The ACU is a heat exchange system developed for broiler houses. The ACU heat exchange system utilizes the thermal energy of the air drawn out of a broiler house to heat incoming air by a countercurrent heat exchange system. The potential ammonia emission reducing principle of the ACU is the drying of the litter mat caused by the heat exchanger and the additional in-house air circulation which is a part of the ACU system.

The heated incoming air that has passed through the ACU is blown to the ridge of the broiler house (Figure 3). The system includes an internal mixing of in house air which potentially results in homogenization of in-house temperatures and improved drying of the broiler litter.

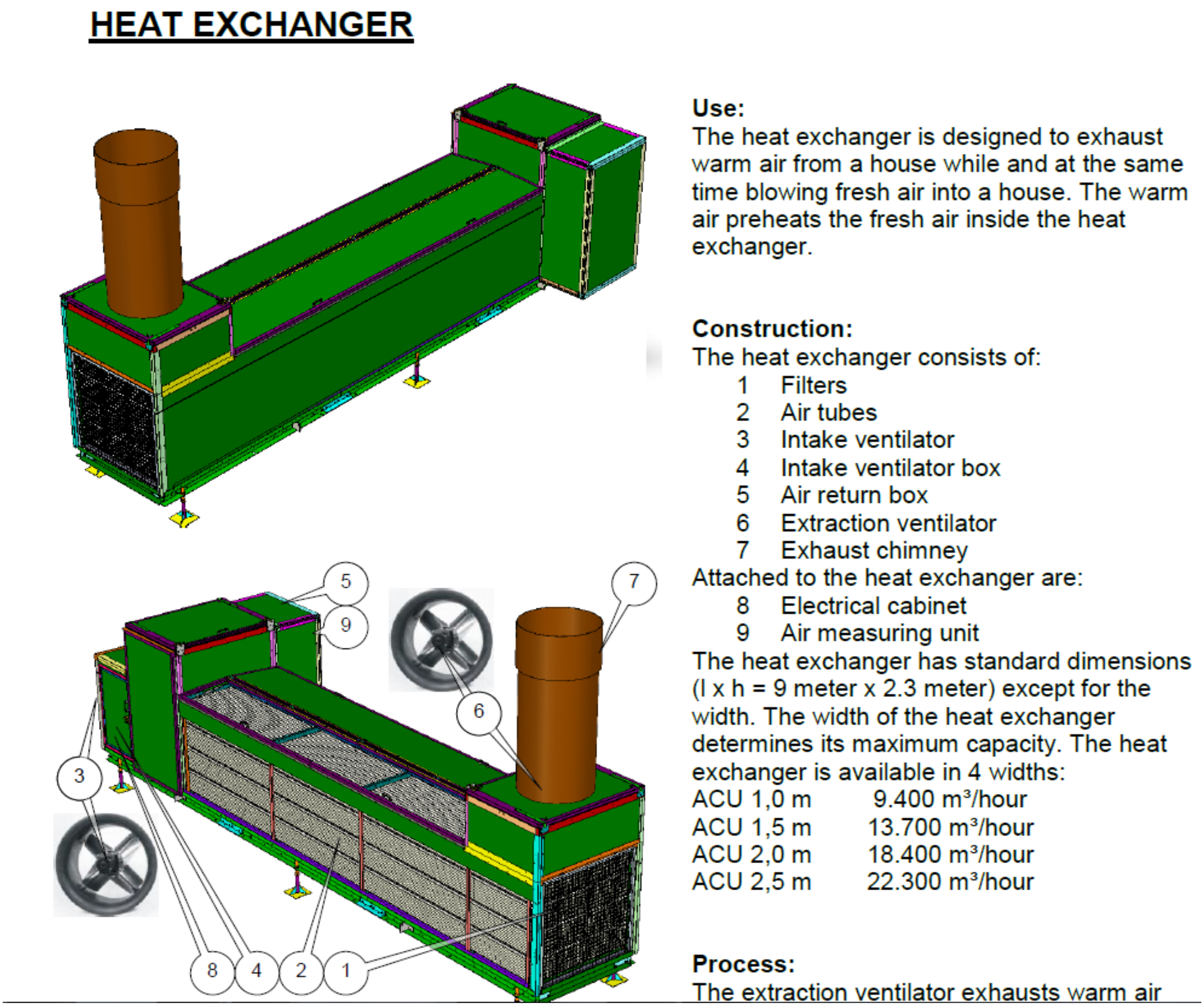


Figure 1. Description of the Agro Clima Unit (ACU) and its main components.

The ACU Clima⁺ 200, type 2.5 has a max air capacity of 22,300 m^3 air h^{-1}. In the first weeks of the production cycle, when the need for heating is high and the need for air exchange (ventilation) is low, the air flow through the ACU is normally gradually increased from 10 to 100 % of its max air capacity. In the last part of the production cycle, when the need for ventilation is higher than the max capacity of the ACU system, the ventilation of the test houses is performed by both the ACU system and the ridge ventilation system. In warm periods the ventilation could be supplemented by gable ventilation.

The ACU units were situated next to the broiler house (Figure 2A).

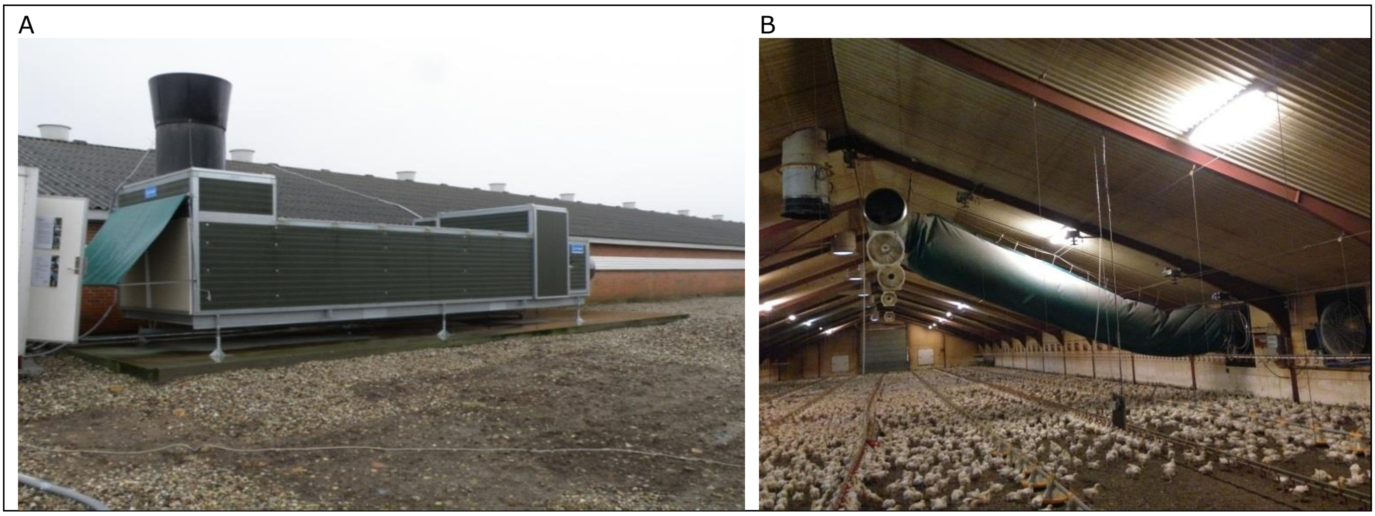


Figure 2. The Agro Clima Unit situated outside a broiler house (A). Ventilation air to and from the broiler house are drawn through the Agro Clima Unit by a countercurrent principle to utilize the heat content of out flowing air to heat up inflowing air. B shows the tube transporting the heated air to the ridge of the broiler house in test farm 1.

Air drawn through the ACU was transported to the ridge of the house (Figure 2B). At the ridge the air was distributed to the front and back side of the building by means of additional in-house circulation fans (Figure 3) to improve the distribution of the fresh and heated air inside the broiler house. The mixed air was drawn by the circulation fans towards both ends of the building at the ridge of the broiler house. The mixed air was then drawn towards the center of the broiler house above the chicken and the litter layer when drawn out by the ACU unit.

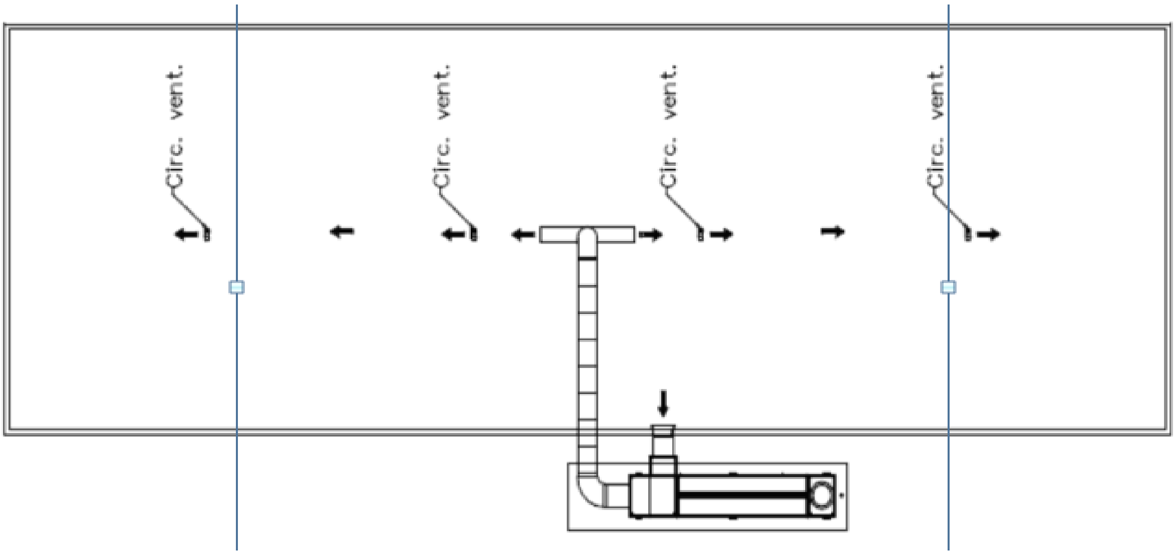


Figure 3. The air circulation system inside the broiler house. Air is drawn through the Agro Clima Unit to the ridge of the broiler house and distributed to the front and back side of the building by means of additional in-house supporting circulation fans (Circ. vents).

2.3.2 User manual

The ACU user manual is included as an appendix to the test report (9.9 AgroSupply User manual).

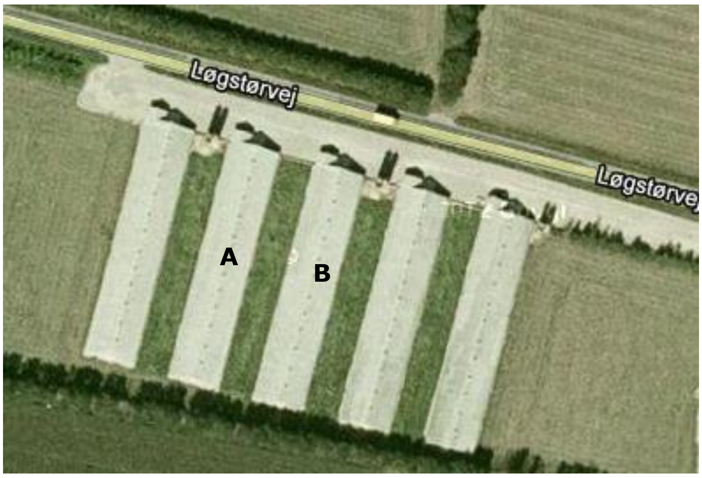
3 MATERIALS AND METHODS

The environmental efficiency and operational stability of the ACU was tested in full-scale on two commercial broiler farms during a 12 month period covering spring, summer, autumn, and winter conditions.

3.1 Test farms

3.1.1 Characterization of the test farms

The test took place at two commercial broiler farms. Both farms have conventional broiler production in housing systems typical for Danish broiler production (Elvstrøm pers com., 2014). At each farm two identical housing units were chosen as test houses. One of the test houses attached an ACU heat exchange system was chosen as case test house (ACU), while the other without the ACU system was chosen as control test house (control). The actual number, age, and size of broilers in the test units were measured and reported for each measuring period.



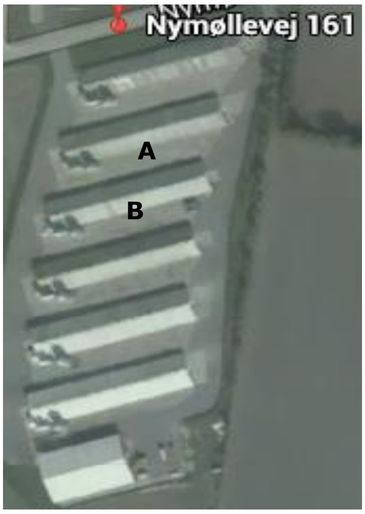


Figure 4. Overview of test farm 1 (left) and test farm 2 (right). The control section is denoted A, while the case section is denoted B.

At both test farms the broiler production took place as an all-in, all-out production. After the broilers were taken out of production at the end of a production cycle, all manure was removed before the housing system was cleaned, disinfected and dried. Thereafter the sections are littered by sawdust and heated to about 33˚C before newly hatched chickens were introduced to the housing system. No manure was taken out during the production cycle. The time interval needed for cleaning, disinfection and drying between the take out of broilers till the introduction of new broilers was seven days.

The heating of the broiler house was performed by use of in-house natural gas burners and straw heated calorifiers (Table 2).

All test houses were equipped with traditional negative pressure ventilation system (Zeihl-Abegg, Ø=630, 13.715 m^3 air h^{-1} (20 pa) ventilations ducts) situated in the ridge. The air exchange through the ridge ventilation ducts were continuously on-line measured by anemometers (Stienen AQC-63) inserted into ventilation ducts (Figure 5A). The test houses were also equipped with on/off gable ventilators. The air exchange through the on/off gable ventilators were measured by registration of running hours and max ventilation capacity (20 Pa) (35.000 m^3 h^{-1}). The measurement of the ventilation through the ACU unit were continuously measured by the anemometer (Ø-72) integrated in the air outlet duct (Ø-106) leading to the ACU (Figure 5B). Fresh air was drawn into the broiler house via adjustable flap ventilation ducts on the entire longitudinal sides of the broiler houses (Figure 5C). All air inlet into the control test houses took place through the flap ventilation ducts, while air inlet into the case test houses took place through the ACU unit and the flap ventilation ducts. The air inlet into the case test houses exclusively took place through the ACU until the ventilation requirement exceeded the air capacity of the ACU unit.

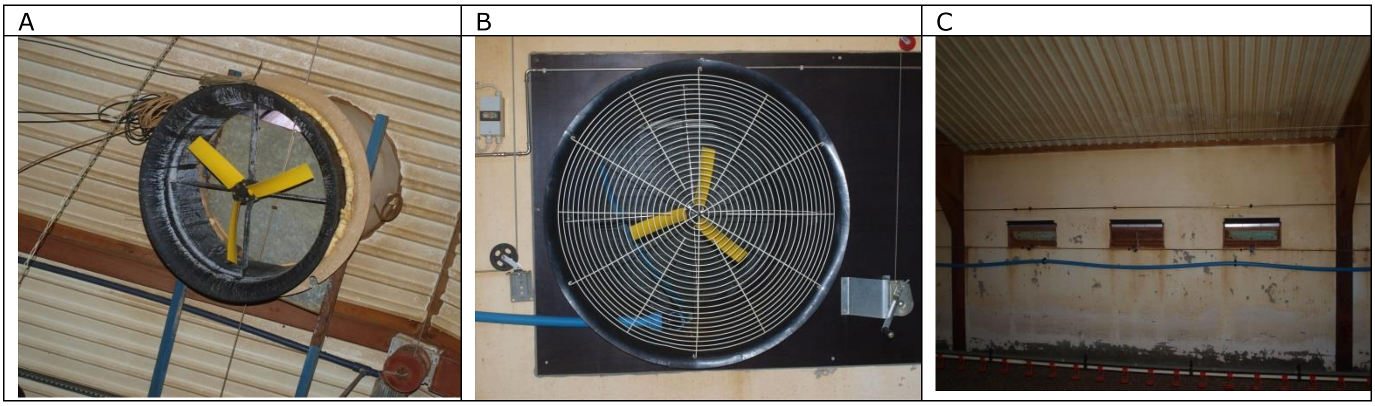


Figure 5. Pictures of air anemometers in ridge ventilation ducts (A) and in the ACU ventilation outlets (B). C shows the adjustable flap ventilation ducts for inflow of air.

The characteristics of the test farms can be seen in Table 2.

Table 2. Key characteristics of test farms.

Parameter	Test farm characteristics Farm 1	Farm 2
Farm owner	Rokkedahl Landbrug	Rokkedahl Landbrug
Address	Løgstørvej 113, 9600, Haubro, Aars	Nymøllevej 161, Kølby 9240 Nibe
Contact Info	Else Olesen, phone:+45 2272 4650	Michael Christensen, phone: +45 20411262
CHR no.	71589	71589
Number of broilers per test unit	Ca. 31.000	Ca. 37.000
Weight range (g) broilers	Newly hatched (45 g) 34/35 days old (ca. 2000 g)	Newly hatched (45 g) 34/35 days old (ca. 2000 g)
Bedding material	Sawdust (25 g/head)	Sawdust (25 g/head)
Area of test houses	1500 m^2	1812 m^2
Dimension test houses (w, l, h (ridge), m	19.6, 77, 6.1	19.6, 96, 6.1
Floor space per animal, m^2	0.05	0.05
Air volume test houses	5961 m^3	7432 m^3
Air volume per animal, m^3	0.19	0.20
Floor system	Solid floor	Solid floor
Manure removal system	All litter is removed at the end of each production period	All litter is removed at the end of each production period
Feed composition	Wheat, proteins (soya), essential amino acids, minerals and vitamins	Wheat, proteins (soya), essential amino acids, minerals and vitamins
Feeding system	Four lines of dry food feeding system	Four lines of dry food feeding system
Feed analysis	Table of content	Table of content
Water system	Four lines of height adjustable and pressure regulated nipple drinking system with drip cups	Four lines of height adjustable and pressure regulated nipple drinking system with drip cups
Ventilation	Mechanical negative pressure ventilation system (Ziehl-Abegg, Ø = 630, Microfan Argos)	Mechanical negative pressure ventilation system (Ziehl-Abegg, Ø = 630, Microfan Argos)
Ventilation capacity (max) (20 Pa)	Ridge:12x12.000=144.000 m^3 h^{-1}, Ø=630 Gable fan: 2 x 35.000 m^3 h^{-1} ACU (test section): 22.300 m^3 h^{-1}, Ø=160	Roof ventilation:13x12.000=156.000 m^3 h^{-1}, Ø=630 Gable fan: 2 x 35.000 m^3 h^{-1} ACU (only test section): 22.300 m^3 h^{-1}, Ø=160
Circulation fans (only test sections)	6 Multifan vertical fans, Ø=500, 7.060 m^3 h^{-1}	6 Multifan vertical fans, Ø=720, 14.600 m^3 h^{-1}
Heating system	In house natural gas burner	Straw heated calorifiers

The test sections were equipped with six vertical circulation fans. The circulation fan system is an integrated part of the ACU system to ensure that air drawn through the ACU system is distributed to the entire broiler house. The circulation fans were vertically situated below the ridge in a way that best possible allowed that incoming ACU heated air were drawn to the front and back of the broiler house (Figure 3). The circulation fans could be regulated both automatically and manually to give between 0 and 100% of maximal air capacity. To ensure optimal in-house climatic conditions, the air capacity of the circulation fans was kept low above newly hatched broilers, and gradually increased to 100% as broilers grew up. A more detailed description of the regulation of the vertical circulation fans can be seen in the user manual (Appendix 9.9, page 78).

The number of newly hatched broilers introduced to the test houses, daily number of sick and dead broilers taken out of the houses, on/off periods of use of gable ventilators, on/off periods of the ACU system, air temperature of test sections, and the daily consumption of feed and water were recorded daily by the test site responsible in prepared log books (Appendix 9.1).

3.2 Integration of pre-test results

The ammonia reduction effect of the ACU unit was pre-tested in the period between August and December 2012. The pre-testing was performed by test methods that fulfilled the requirements of the VERA protocol (VERA, 2011), except that measurements were performed at only one farm location and that ammonia was the only primary parameter measured. The method used and the results of the pre-test are described by Hansen et al. (2012).

The pre-test was performed as three continuous measuring periods lasting from one week after the broilers were introduced into the housing system till a fraction of the batch was taken out of production 30 days old. The observed data was used to calculate an average emission rate for the initial, medium and last part of the production period. Each period was set to 11 days in accordance to an average total production period of 34 days. These calculated emission rates were integrated as pre-tested measurements data (Table 3).

As the pre-test was performed in the period between August and January, three out of the requested six ammonia measurements periods per test farm were considered completed by the pre-test. These results were integrated into the test report. The number of measuring events completed by the pre-tests, and the requested additional number of measurement periods at the two test farms can be seen in Table 3 and Table 4.

Table 3. Number of requested measurement periods for ***ammonia*** *emission measurement, the number of measurement periods completed in pre-test and required additional measurement periods.*

	Requested by the protocol			Completed in pre-test			Additional measurements periods		
Broiler growth stage	Farm 1	Farm 2	In total	Farm 1	Farm 2	In total	Farm 1	Farm 2	In total
Initial (0-11 days)	1	1	2	1	0	1	0	1	1
Medium (12-23 days)	2	2	4	1	0	1	1	2	3
Last (24-34 days)	3	3	6	1	0	1	2	3	5
Total	6	6	12	3	0	3	3	6	9

Table 4. Number of requested measurement days for ***odour*** *emission measurements, number of measurement days completed in pre-test, and required additional measurements periods.*

	Requested by the protocol			Completed in pre-test			Additional measurement days		
Broiler growth stage	Farm 1	Farm 2	In total	Farm 1	Farm 2	In total	Farm 1	Farm 2	In total
Initial (0-11 days)	1	1	2	0	0	0	1	1	2
Medium (12-23 days)	3	3	6	0	0	0	3	3	6
Last (24 - 34 days)	5	5	10	0	0	0	5	5	10
Total	9	9	18	0	0	0	9	9	18

3.3 Test procedure

3.3.1 Test parameters

Odour and ammonia were the primary performance test parameters. In addition, a number of conditional parameters were measured throughout the test periods.

Primary parameters

The primary analytical parameters are presented in *Table 5*. The primary measurement parameters are the primary environmental pollutants emitted from broiler housing unit. These were therefore considered the primary target of the environmental technology.

Dust was not included as a primary parameter. This decision was based on the assumption that the vast majority of the dust produced in broiler houses originates from feathers and the activity of the broilers (Elvstrøm. Pers. com.. 2014), and that a previous preliminary dust study performed by the test institute LUFA NordWest had found reduced levels of dust from broiler houses attached a heat exchange system This study which was performed on behalf of the technology producer Big Dutchman, found that the use of the heat exchange system (Earny) reduced the dust emission from broiler houses by between 11 to 28% (Big Dutchman, 2014). Therefore, as the dust emission was judged to be unaffected or reduced by use of the technology tested, dust was not included as a parameter in the test.

Table 5. Primary test parameters and corresponding analytical methods and detection limits

Parameter	Analytical method	Number of samples	Sampling time/period	Limit of detection	Uncertainty
Ammonia	Photo accustic mulitgas analyzer (Innova 1412)	6 measuring periods evenly distributed over one year	Min 24 hours	0.14 mg/m^3	15 % RSD
Odour	Olfactometric analyses. (DS EN ISO/IEC 17025 EN 13725 (71M549500) DANAK Test reg. nr. 522)	9 measuring periods (of which minimum 6 were performed during summer period (May to September)	30 minutes	100 OU_E/m^3	±2 x RSD

Conditional parameters

The conditional parameters are listed in Table 6. The conditional parameters are parameters which may influence the emission level of the primary environmental pollutants. In addition, the table includes additional secondary environmental pollutants.

Table 6. Conditional parameters, involved analytic methods and detection limits

Parameter	Analytical method	No of measuring periods	Sampling time/period	Limit of detection	Uncertainty
CO_2	Photo acoustic multigas analyzer (INNOVA, 1412)	6	Continuous	2.5 mg/m^3	15 % RSD[1]
Air Temperature	Motron, Smart sence 3000 coupled to VE10A VENG universal input system	6	Continuous	-40 - +60˚C	±0,5˚C (0-40˚C)
Relative air humidity	Motron, Smart sence 3000 coupled to VE14 universal VENG system	6	Continuous	0,1% RH	±2% (10-90% RH)
Ventilation	Air anemometers, Steinen AQC-630	6	Continuous	2 $m^3 s^{-1}$	
H_2S (odour sampling)	Jerome 631-X™	9	10 min	3 ppb	0.003-2 ppm[2]
NH_3 (odour sampling)	Kitagawa gas detection tubes, 0.2 – 20 ppm	9	2 min	0.1 ppm	5% RSD
Air Temperature (odour sampling)	Testo 174H	9	60 min	0.1 °C	±0.5 °C (-20 to +70 °C)
Relative air humidity (odour sampling)	Testo 174H	9	60 min	0.1 %	±3 %RH (2 to 98 %RH)
Manure parameters	Accredited standard laboratorie analyses				
- DM (%)	DIN EN 12880	6			
- Total N (kg/ton)	DIN 19684-4	6			
- NH4-N (kg/ton)	DIN 38406-5-2	6			
Wind direction (˚) and speed (m/s)	UTM based climatic data service developed by the Danish Meteorological Institute (DMI)	9	24 h		

1. RSD: Relative standard deviation
2. Depending on concentration

3.4 Test activities

The test activities were undertaken by AgroTech Test Centre. All activities were performed according to the AgroTech quality management system covering test activities that follows the principles of DS/EN ISO 9001. The ISO 9001 certification includes tests of environmental technologies and bioenergy technologies. A copy of the DS/EN ISO 9001 certificate can be seen in appendix 9.4.

Procedures ensuring that test facilities and equipment are calibrated and fit for the purposes are described by the AgroTech quality Management System Manual (AgroTech, 2014). These procedures are subject to internal audits from the AgroTech Management system and extern audits performed by the DNV Business Assurance.

3.5 Analysis of samples

3.5.1 Manure analyses

All manure analyses were carried out by Agrolab, Institut Koldingen GmbH, Breslauer Strasse 60, 31157 Sarstedt, Germany. Agrolab holds an accreditation according to EN ISO/IEC 17025 (Anlage Zur Akkreditierungsurkunde D-PL-14047-01-00 nach DIN EN ISO/IEC 17025:2005) submitted by the German National Accreditation Body, DAkkS) (DAkkS, 2015).

3.5.2 Ammonia analysis

The ammonia concentration in air was measured by use of a photoacoustic multigas detector (Innova 1412, Lumasense Copenhagen) coupled to a multiplexer (Innova 1307, Lumasense Copenhagen). By use of the photoacoustic gas analyser the ammonia concentration of inflowing and exhaust air were automatically continuously online sampled and analysed during the measuring period.

The stability of the measuring system was ensured by use of annually calibrated measuring systems and by supervision during recording of data. The equipment was last calibrated 09.01-2015.

Before start of the sampling period the performance of the gas analyser was inspected and controlled by simultaneously analyses of gas concentration by Kitagawa gas detection tubes and the photoacoustic analyser to inspect for technical malfunction of the gas analyser, and to detect leakages or filter blockages of the air sampling system.

Procedures ensuring that test facilities and equipment were calibrated and fit for the purposes are described in the AgroTech quality Management System Manual (AgroTech, 2014). These procedures are subject to internal audits from the AgroTech Management system and extern audits performed by the DNV Business Assurance.

3.5.3 Odour analyses

The odour concentration in outflowing air were analysed by dilution olfactometric analyses carried out by an external odour analytic institute (EuroFins, Galten, Dk). All analyses were performed in accordance to the accreditation standard: DS EN ISO/IEC 17025 DANAK Test reg. No. 522.

3.6 Preservation and storage of samples

Ammonia

Kitagawa gas detection tubes were used for quantification of ammonia concentration in odour samples. When used the samples were analysed as soon as possible after sampling. The ammonia concentration was quantified because ammonia can be an odour nuisance at high concentration, and to ensure that the odour sampling took place through intact sampling tubes. By comparing the ammonia concentration in air sampled for odour analyses and the ammonia concentration measured in in-house air it was ensured that the odour air samples were sampled through non-leaky sampling tubes.

Manure samples

Immediately after sampling manure samples were stored as cool as possible. Within 5 hours the samples were frozen until sent to analytical analyses.

Odour samples

Odour samples were sampled, stored and handled according to the description given by Miljøstyrelsen (2006) regarding sampling and analyses of odour samples from livestock production units.

3.7 Test design and sampling methods

The overall principle for testing the ACU performance was to compare the emission of ammonia and odour from test broiler houses with the ACU heat exchange system (ACU) and the emission of ammonia and odour from an equal test section without the ACU technology (Control). As broilers are housed in mechanically ventilated housing systems, the emissions were quantified by simultaneously on-line measurements of air exchange rate (ventilation) and concentrations of gases in ingoing and outgoing air.

3.7.1 Determination of ventilation

Emission measurements from livestock housing systems require measurement of the total ventilation of the housing systems. The ventilation rate during the measurement periods was continuously on-line measured by introducing air anemometers into ventilation ducts during the test period.

The ventilation rate gives the volume flow of air drawn out from the broiler house. The direct techniques for measuring air exchange involve measurements of the airflow capacity of the farm exhaust air ducts by use of air fans (anemometers). The ventilation of broiler houses is computed based on the manufactured specified fan performance curve for the specific ventilation installation; however, such calculation can introduce error due to altered fan curve arising from uncontrollable variables; such as loose fan belt, partially open and dirty shutters, and dirty fan blades. Due that, the direct measurement method was chosen. The direct method involved use of portable fan wheel anemometers situated in ridge air outlets.

The ridge ventilation took place through either 12 or 13 roof ventilation outlets (Table 2). The individual ridge ventilation outlets were identical and controlled by the same climate controlling system to ensure equal ventilation rate of individual ventilation outlets. The equality of air flow and gas concentrations of the individual ridge ventilation ducts were onsite evaluated on each test farm by use of air anemometer (Testo anemometer 417) and CO_2 and ammonia gas detection tubes (Kitagawa) to ensure equality of ammonia concentrations and air flow between the individual ridge ventilators attached to each test broiler house (appendix 9.6). A high level of equality regarding both air flow and gas concentrations of the individual ridge air outlets were observed with Coefficient of Variation (CV) lower than 5% for measurements performed at the test houses both regarding gas concentrations and airflow (appendix 9.7.)

In addition to the ridge ventilation system the broiler test houses were equipped with two gable wall ventilators, which were put into use when required as a supplement to the ridge exhaust units. The gable wall ventilators were only put in use when the external temperatures were high, and in the last part of the production cycle when the ventilation requirement was at the highest. The gable wall ventilators were manually on-off regulated and use of gable fans was recorded by the farm manager. The gable wall ventilators were only put into use in one of the performed measurement periods (16 – 26 August, 2015 at test farm 2).

The specific method involved in measurement of the air flow from the test sections is described in detail in "Instruction for Airflow measurements" (Cortina, A.G., 2013).

3.7.2 Air sampling system

During test periods air was continuously drawn from measuring points to the measurement system via insulated and heated Teflon tubes. The air sampling took place from measuring points in air outlet points (ridge ventilation ducts, ACU air inlet and outlet, and background air. The specified sampling points can be seen in Figure 6.

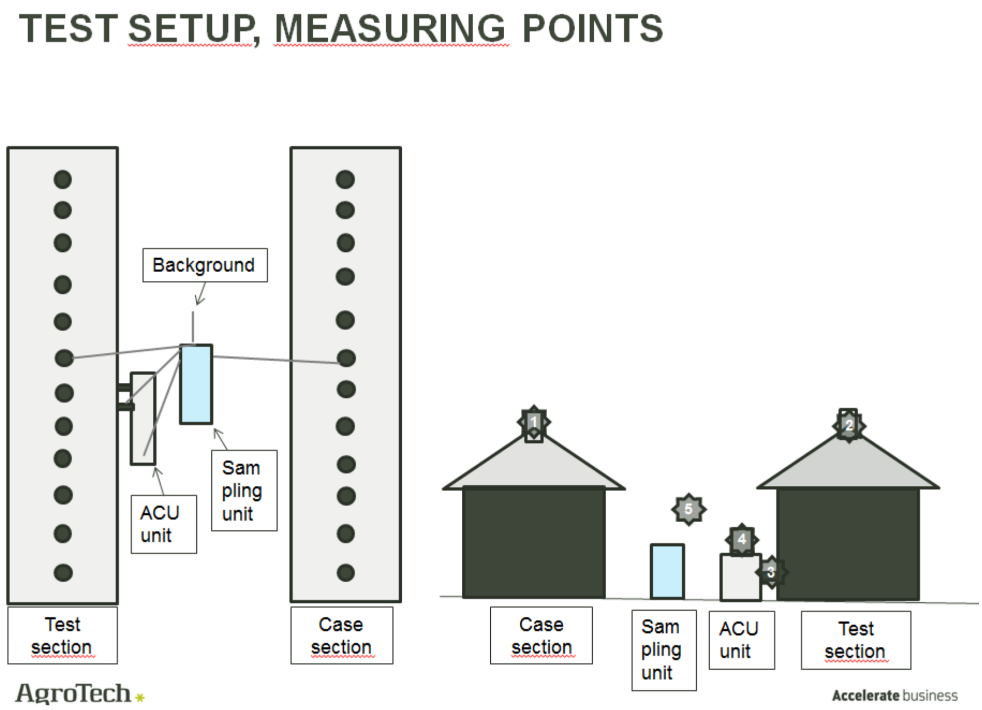


Figure 6. Schematic drawing of sampling points and measurement equipment (sampling unit). The air sampling took place by drawing air via insulated and heated Teflon tubes from one of the roof ventilation ducts (1 and 2), ACU air inlet and outlet (3 and 4), and from background air (5) to the measurement equipment situated inside the sampling unit.

3.7.3 Determination of ammonia emission

The concentrations of ammonia in in- and outflowing air was during the measuring periods continuously on-line measured by use of an on-line photoacoustic multigas analyser (INNOVA, 1412), connected to an automatic multipoint sampler (INNOVA, 1307). Air was drawn by diaphragm pumps from the sampling points to the measuring equipment through insulated and heated Teflon tubes to avoid vapor condensation in tubes and measuring system. The measured levels of gas concentrations in in- and outflowing air were inspected twice daily to detect filter blockage and technical malfunctions.

Each ammonia measurement period lasted 24 hours or more. When possible the measurement period was prolonged to decrease effects of daily variations. When the measurement period was prolonged the daily ammonia emission rate was calculated based as the average of the number of days involved in the measurement period. To avoid influence of daily variation, the measurement was prolonged by either 24, 48 or 72 hour.

The ammonia measuring system (INNOVA 1412) was attached a multiplexer (INNOVA, 1307) that automatically switched between the five sampling points. At each sampling point the gas measurements were repeated ten times to overcome the sampling issues related to the stickiness nature of ammonia in sampling tubes and measurement system, before the measurements were automatically switched to the next sampling point. By this method the gas measurements at each sampling point were repeated at hourly basis.

The emission of ammonia from the test units was quantified by the following equation:

$$E_{NH3} = \sum_{i=1}^{i=3} \sum_{t=1}^{t=n} \bar{V}_{i_t}\, x\, (\bar{C}_{out_{i_t}} - \bar{C}_{in_{i_t}})$$

where
E_{NH3} = Total loss of ammonia from the housing systems at the measurement period, mg NH_3
i = Type of ventilation (roof ventilation, Agro Clima Unit ventilation, gable wall ventilation)
n = The number of samplings hours during the sampling period
V_i = Air flow, m^3 air h^{-1}

C_{in_t} = Ammonia concentration in inflowing air at hour t, mg NH_3 m^{-3} air
C_{out_t} = Ammonia concentration in outflowing air at hour t, mg NH_3 m^{-3} air
t = Measurement hour

The daily emission of ammonia per housed broiler was quantified by the following equation:

$$E_{NH_3} = \frac{24}{n * N_j} \; x \; \bar{E}_{NH3_j}$$

Where
E_{NH3} = Daily ammonia emission per head, mg NH_3 $head^{-1}$ day^{-1}
n = Length of the measurement period, hours
j = Measurement day
N_j = Total number of broilers in test section
$\bar{E}_{NH3_t}$ = Mean measured ammonia emission per test house at hour j, mg NH_3 h^{-1}

The ammonia emission from both the ACU and control sections was measured by six cumulative sampling periods per test house, each lasting 24 hours or more. According the test requirement, one of the test periods was performed when the broilers were between 1 and 11 days old, two test periods were performed when the broilers were between 12 and 23 days old, and three test periods were performed when the broilers were between 24 and 34 days old. The six measuring periods took place so that the measurement periods were as equally as possible distributed over a production year to incorporate a potential climatic effect. See section 3.8 for details.

The ammonia measuring system (Innova 1412) was onsite validated prior to the start of each ammonia measurement period. The validation was performed to check for drift of the measuring system and technical failures or blockage of filters. The onsite validation was performed by comparing simultaneous ammonia sampling performed by use of the photo acoustic multigas monitor system and Kitagawa ammonia gas detection tubes. If deviations between sampling results or technical problems regarding the measuring system were observed, the problem was identified and repaired. If the problems were related to the INNOVA measuring system this was sent for repair and recalibration and the scheduled measurements were performed by use of another similar photo acoustic measuring system (INNOVA 1412).

The ammonia concentration was quantified in background air, in air sampled in ridge ventilation ducts, and in air sampled in ACU inlet and outlet. The ammonia concentration in the ACU outlet air was used for calculating the ammonia emission through the ACU system when possible. However, in test periods of high indoor air humidity and high washing frequency of the ACU system, the sampling of ACU outlet air was impeded due to vapor and condensation problems. In these situations, the ammonia concentration of the ACU inlet was used for calculation of the ammonia emission via the ACU system.

The average ammonia emission per growth stage and test farm was calculated as the mean of number of measurements periods performed at each test farm.

$$\bar{E}_{p_{gj}} = \frac{1}{i} \sum E_{NH3_{gi}}$$

where
$\bar{E}_{p_{gj}}$ = Average ammonia emission at growth stage g in test farm j, in mg NH_3 $head^{-1}$ day^{-1}
g = growth stage, 1, 2, 3
i = measurement period
j = test farm

Data obtained at the different test farms were analysed for equal variance by F test and difference of means by t-test. If means were not found statistically different means per production periods were pooled before further analysed by the following equation

$$\bar{E}_{p_g} = \frac{1}{n_g} \sum E_{NH3_{gj}}$$

where
$\bar{E}_{p_g}$ = Average ammonia emission at growth stage 1, 2 or 3, in mg NH_3 $head^{-1}$ day^{-1}
n_g = Number of measurement period in growth stage g

The total ammonia emission per production period was calculated by dividing the production period into three growth stages of equal length, and multiplying the measured ammonia emission rate by the number of days per growth stage.

$$E_t = \sum N_g \, x \, \bar{E}_{p_g}$$

where
E_t = the total ammonia emission per production period, mg NH_3 head^{-1} production period^{-1}
N = number of days in growth stage g
g = growth stage, 1, 2, 3

3.7.4 Determination of odour emission

The principle for determination of odour emission is quantification of ventilation rate and the odour concentration of air leaving the animal house. Each measurement day three odour samples were simultaneously sampled at each test house in 30 l Nalophan odour bags with a sampling period of 30 minutes. Within the ISO 17025 accreditation scope, the Nalophan material is tested according to No. 6.3.2 of the European Norm EN 13725 and No. 4.3.1 of the German guideline VDI 3880 and is released as norm-compliant material for odour sampling.

The odour bags were filled by use of vacuum containers. The odour concentration of the sampled air was subsequently quantified by dilution olfactometric analyses within 24 hours after sampling.

The odour sampling system was mobile. Once at the test site, the vacuum containers were prepared and connected to diaphragm pumps with a controlled airflow. The vacuum was regulated so that the odour sampling time was 30 minutes per sample. Marked odour bags were then inserted into the vacuum containers and the inlet of the bags were connected to the measuring point by Teflon tubes.

Before test sampling, the odour bags were conditioned by filling the odour bags with air drawn from the measuring points and afterwards emptying the bag.

The odour samples were sampled in the outlet of the ventilation system (ridge, ACU or gable wall) performing the highest proportion of the total ventilation at the sampling period. To avoid possible effects of increased humidity in air sampled in the outlet of the ACU system, odour samples from the ACU system were sampled at the inlet to the ACU system.

After test sampling the odour samples were stored in closed cardboard boxes or black plastic bags to avoid exposure to direct sunlight. Climatic and environmental conditions that may influence the odour emission were recorded at the odour sampling event in prepared look books (Appendix 9.2).

According the specific Danish requirement regarding odour sampling six odour measurements took place during summer period, while three odour measurement periods were evenly distributed outside the summer period.

The odour emission per broiler was calculated by the following equation:

$$\boldsymbol{E_{OU_E j}} = \frac{\mathbf{1}}{60 * 60 * \boldsymbol{N_j}} * \overline{\boldsymbol{OU_{EJ}}} * (\boldsymbol{V_j})$$

Where
$\boldsymbol{E_{OU_E}}$ = *Odour emission per head and second, Odour Units (OU_E) head^{-1} s^{-1}*
$\overline{\boldsymbol{OU_E}}$ = *Average measured odour concentration, OU_E m^{-3} air*
V_j = Air exchange rate of test section, *m^3 air h^{-1}*
N = Total number of animals in test section
j = Measurement period.

3.7.5 Determination of manure composition and humidity

Representative samples of broiler litter were sampled in connection to the ammonia sampling periods. From each test house three manure samples, each consisting of ten manure subsamples collected randomly in a line diagonally the length of the building, were collected. The subsamples were thoroughly mixed in airtight plastic bags. As soon as possible and before five hours the samples were stored at -18°C before analyzed for dry matter content and nutrient composition.

3.7.6 Determination of air temperature and air humidity

Air temperature and humidity of indoor and outdoor air were online measured during sampling periods by use of Motron, Smart sence 3000 temperature and humidity sensors coupled to VE10A and VE14 VENG universal input logging system. The sensors were situated in ridge ventilation ducts inside the broiler house and in the shadow outside the test houses. Both systems were onsite validated during ammonia sampling periods by comparative simultaneous measurements performed by Testo 174H temperature and humidity data-logger sensors situated in indoor and outdoor air.

3.7.7 Statistical analyses

The mean and the median ammonia and odour emission were calculated for the individual test locations and test periods. Results obtained at the two test farms were analysed for equal variance by F test (p=0.05) (Microsoft analysis Toolpack), before significant difference between results obtained at the two test farms were identified by pairwise t-test (p=0.05). Data with unequal variance were ln transformed to obtain equal variance before statistical analysed. When no statistical differences were found between the two test farms data obtained at the two farms were pooled before further analysed.

Results obtained from broiler houses with and without the ACU technology at the different growth stages were analysed for equal variance by F test (p=0.05). Differences of means of measured emission levels from control and the ACU broiler houses were tested by pairwise t-test (p=0.05) (Microsoft analysis Toolpack).

3.8 Test schedule

The test was performed over a full year starting August 2014 and ending September 2015.

The test schedule for odour emission periods is presented in Table 7.

Table 7. List of odour measuring dates. Six of the measuring dates were performed at summer conditions (May to September), while three were performed at winter conditions (October to April)

Measurement period	Farm 1		Farm 2	
	Summer/winter period	Measurement day	Summer/winter period	Measurement day
Period 1	Summer	11.09-2014	Summer	20.08-2014
Period 2	Winter	10.12-2014	Summer	11.09-2014
Period 3	Winter	02.02-2015	Winter	09-10-2014
Period 4	Winter	19.03-2015	Winter	04.12-2014
Period 5	Summer	03.06-2015	Winter	24.02-2015
Period 6	Summer	16.06-2015	Summer	07.05-2015
Period 7	Summer	21.07-2014	Summer	20.05-2015
Period 8	Summer	29.07-2015	Summer	12.08-2015
Period 9	Summer	03.09-2015	Summer	20.08-2015

The test schedule for the ammonia emission periods at the two test farms is presented in Table 8.

Table 8. List of start and end of the ammonia measuring periods.

Measurement period	Farm 1		Farm 2	
	Start	End	Start	End
Period 1	22.08-2012 (pretest)	02.09-2012 (pretest)	07.10-2014	09.10-2014
Period 2	15.10-2012 (pretest)	26.10-2012 (pretest)	04.12-2014	06.12-2014
Period 3	12.12-2012 (pretest)	23.12-2012 (pretest)	13.03-2015	14.03-2015
Period 4	18.03-2015	23.03-2015	18.05-2015	20.05-2015
Period 5	01.06-2015	03.06-2015	07.08-2015	12.08-2015
Period 6	12.06-2015	14.06-2015	18.08-2015	20.08-2015

4 RESULTS AND DISCUSSION

4.1 Effects of technology on air humidity and litter

Use of a heat exchange system influences the internal ventilation and the humidity of air inlet. This was expected to affect indoor air humidity and dryness and nutrient content of broiler litter.

The observed results regarding indoor air humidity and dryness and nitrogen content in broiler litter can be seen in Table 9 and Table 10. The indoor air humidity was in general found to be lower in the broiler house attached the heat exchange system. However, higher air humidity was observed in the ACU test house in the first part of the production period. The higher observed air humidity is expected to be the fact that the humidity sensors were situated in the ridge ventilation ducts and that these in the ACU houses were not in use in the first part of the production period when the ventilation was performed solely by the heat exchange system. Later in the production period the in-door humidity was found to be lower in test houses heated by the ACU system (Table 10).

Table 9. Indoor air temperature and humidity, and dry matter and nitrogen content in broiler litter sampled in the broiler house without heat exchange system (Con) and in the broiler house with heat exchange system (ACU) at test farm 1.

Test period	Treatment	Sampling date, dd-mm-yy	Age of broilers, days	Indoor air temperature, ˚C	Indoor air humidity, % RH	Manure dry matter content, %	Manure NH_4-N content, kg N/ton dm	Manure total N content, kg N/ton dm
1	Con	28-8-2012	8	31.9	49.5	N.D[1].	N.D[1].	N.D[1].
	ACU	28-8-2012	8	28.7	54.4	N.D[1].	N.D[1].	N.D[1].
2	Con	21-10-12	16	28.2	59.6	N.D[1].	N.D[1].	N.D[1].
	ACU	21-10-12	16	28.2	54.9	N.D[1].	N.D[1].	N.D[1].
5	Con	3-6-2015	16	27.8	ND[2]	68.5	2.9	39.6
	ACU	3-6-2015	16	26.0	59.0	68.5	2.7	37.9
3	Con	19-12-12	27	22.3	70.5	N.D[1].	N.D[1].	N.D[1].
	ACU	19-12-12	27	22.2	58.4	N.D[1].	N.D[1].	N.D[1].
4	Con	21-3-15	32	22.2	72.2	47.1	2.9	36.9
	ACU	21-3-15	32	20.5	62.1	53.5	2.5	29.9
6	Con	13-6-15	27	23.4	61.7	58.7	5.8	42.8
	ACU	13-6-15	27	22.2	60.2	54.8	5.6	40.0

1. No manure analyses were performed on pre-study test 2012
2. No results due technical malfunction of humidity sensor

Table 10. Indoor air temperature and humidity, and dry matter and nitrogen content in broiler litter sampled in the broiler house without heat exchange system (Con) and in the broiler house with heat exchange system (ACU) at test farm 2.

Test period	Treatment	Sampling date, dd-mm-yyyy	Age of broilers, Days	Indoor air temperature ˚C	Indoor air humidity, % RH	Manure dry matter content, %	Manure NH_4-N content, kg N/ton dm.	Manure total N content, kg N/ton dm.
3	Con	14-03-2015	4	31.3	52.5	79.3	2.9	36.9
	ACU	14-03-2015	4	31.6	55.3	80.6	2.5	29.9
5	Con	10-08-2015	18	26.7	67.9	66.1	4.0	42.3
	ACU	10-08-2015	18	27.4	66.6	71.7	3.4	54.1
1	Con	09-10-2014	16	27.2	73.0	67.3	4.2	36.5
	ACU	09-10-2014	16	28.4	66.9	66.8	4.6	42.0
2	Con	05-12-2014	31	21.9	67.1	ND[2]	ND[2]	ND[2]
	ACU	05-12-2014	31	22.1	70.2	ND[2]	ND[2]	ND[2]
4	Con	19-05-2015	28	20.8	67.2	65.0	6.5	45.1
	ACU	19-05-2015	28	21.6	66.8	68.6	7.9	52.3
6	Con	19-08-2015	28	22.2	67.3	N.D[1]	N.D[1]	N.D[1]
	ACU	19-08-2015	28	23.2	65.8	N.D[1]	N.D[1]	N.D[1]

1. No manure sampling performed
2. Identification marks on litter samples were lost during storage.

Considerable variation was observed regarding dry matter and nitrogen content of broiler litter

Table 9) and (Table 10). The high variation is considered to be due the challenges regarding collecting representative samples of the heterogeneous broiler litter mat. The dry matter content of the litter mat was in general higher in the broiler houses attached the heat exchange system than in the broiler houses without heat exchange system, but this was not consistent. The reason for this can be that early in the production cycle, faeces excreted by the broilers only make up a minor part of the litter mat (mainly consisting of litter). A faster desiccation of excreted faeces caused by the lower humidity of in-door air may therefore only have minor impact on dry matter content of the total litter mat. Contrary lower content of ammonium nitrogen (NH_4-N) were in general observed in the litter mat in the broiler houses attached the heat exchange system. This indicates a lower turnover of the uric acid excreted by the broilers due lower litter humidity.

4.2 Odour emission

Table 11. Samplings dates, conditional parameters and mean odour concentration and emission at test periods performed at control (Con) and ACU test broiler houses at test farm 1.

Test period	Treatment	Sampling date, dd-mm-yyyy	No of broilers	Age of broilers, Days	Start measurement, hh:mm	Outdoor temperature °C	Indoor air temperature °C	Ventilation rate, m^3 h^{-1}	Odour concentration, OU_E m^{-3}	Odour emission, OU_E $head^{-1}$ s^{-1}	Odour emission, OU_E LU^{-1} s^{-1}
1	Con	11-09-2014	30804	10	10:58	25.2	28.7	9,956	430	0.04	74.0
	ACU	11-09-2014	30780	9	10:09	22.6	28.2	7,865	687	0.05	93.4
2	Con	10-12-2014	30453	15	11:24	7.2	27.9	19,237	350	0.06	54.3
	ACU	10-12-2014	30626	15	10:28	5.7	25.76	13,517	1500	0.18	162.5
3	Con	02-02-2015	31204	27	13:30	-1.0	24.4	30,970	1300	0.36	122.7
	ACU	02-02-2015	30803	28	12:30	-1.0	20.3	25,345	867	0.20	67.8
4	Con	19-03-2015	31289	30	09:40	7.9	24.4	22,985	2000	0.41	124.7
	ACU	19-03-2015	30900	30	11:00	10.3	21.9	23,985	2167	0.47	142.7
5	Con	03-06-2015	26158	16	09:15	12.3	26.9	26,149	497	0.14	116.1
	ACU	03-06-2015	26125	16	10:15	13.7	25.7	17,988	820	0.16	132.0
6	Con	16-06-2015	25983	29	08:50	12.4	22.6	37,654	1103	0.44	143.5
	ACU	16-06-2015	25897	29	10:00	12.9	21.2	38,487	700	0.29	93.3
7	Con	21-07-2015	26474	19	09:38	17.1	24.5	N.D.	1667	N.D.	N.D
	ACU	21-07-2015	24405	19	10:44	17.2	26.8	N.D.	2300	N.D.	N.D
8	Con	29-07-2015	26339	27	09:15	16.9	23.4	52,910	1600	0.89	339.5
	ACU	29-07-2015	24259	27	10:10	18.6	22.9	46,675	1013	0.54	205.9
9	Con	03-09-2015	27695	16	10:45	16.4	26.35	16,346	1533	0.25	228.1
	ACU	03-09-2015	25303	16	11:40	17.4	26.8	20,786	1150	0.26	238.1

Table 12. Samplings dates, conditional parameters and odour concentration and emission at test periods performed at control (Con) and ACU test broiler houses at test farm 2.

Test period	Treatment	Sampling date, dd-mm-yyyy	No of broilers	Age of broilers, Days	Start measurement, hh:mm	Outdoor temperature °C	Indoor air temperature °C	Ventilation rate, m^3 h^{-1}	Odour concentration, OU_E m^{-3}	Odour emission, OU_E $head^{-1}$ s^{-1}	Odour emission, OU_E LU^{-1} s^{-1}
1	Con	20-08-2014	37536	8	10:24	14.7	33.7	4,120	1020	0.03	69.4
	ACU	20-08-2014	36805	8	11:41	13.5	29.7	3,978	1300	0.04	87.1
2	Con	11-09-2014	37177	30	14:47	23.49	24.2	173,212	357	0.46	136.9
	ACU	11-09-2014	36267	30	13:50	22.49	22.68	166,229	360	0.46	135.9
3	Con	09-10-2014	36084	16	10:00	15.99	27.12	17,334	997	0.13	117.5
	ACU	09-10-2014	35420	16	11:22	16.81	28.5	14,190	1833	0.20	180.2
4	Con	04-12-2014	36953	30	10:35	4.18	22.12	94,036	763	0.54	169.0
	ACU	04-12-2014	36410	30	11:35	4.31	21.32	71,084	1450	0.79	246.4
5	Con	24-02-2015	35883	28	11:25	4.8	22.37	29,777	1533	0.35	121.0
	ACU	24-02-2015	35812	28	10:05	4.5	21.5	34,138	1400	0.37	126.9
6	Con	07-05-2015	31245	16	09:15	10.8	27.35	13,644	1273	0.15	123.8
	ACU	07-05-2015	32328	16	10:15	9.1	26.38	24,842	647	0.14	116.2
7	Con	20-05-2015	30957	29	09:15	12.1	20.43	55,887	417	0.21	65.5
	ACU	20-05-2015	32076	29	10:15	11.3	21.95	62,401	557	0.30	94.2
8	Con	12-08-2015	31765	20	10:00	17.2	25.8	36,846	1083	0.35	207.5
	ACU	12-08-2015	31065	20	11:00	18.1	27.1	37,331	1233	0.41	244.8
9	Con	20-08-2015	31612	28	10:35	20.9	22.5	196,475	170	0.29	106.6
	ACU	20-08-2015	30899	28	11:30	22.3	23.88	185,795	130	0.22	78.9

The odour emission from the control and the case (ACU) broiler houses at the two broiler test farms was measured by nine test periods. Six of the test periods took place during summer conditions (May to September) and three took place at outside the summer period. The relevant parameters and odour concentration and emission are summarized in Table 11 and Table 12.

The odour emission varied considerable between the different test periods. The variation is considered to be caused by differences in climatic condition and size of broilers. The mean odour emission per growth stage 1 (broiler age 1-11 days), growth stage 2 (broiler age 12-23 days), and growth stage 3 (broiler age 24-34 days) was therefore calculated (Figure 7).

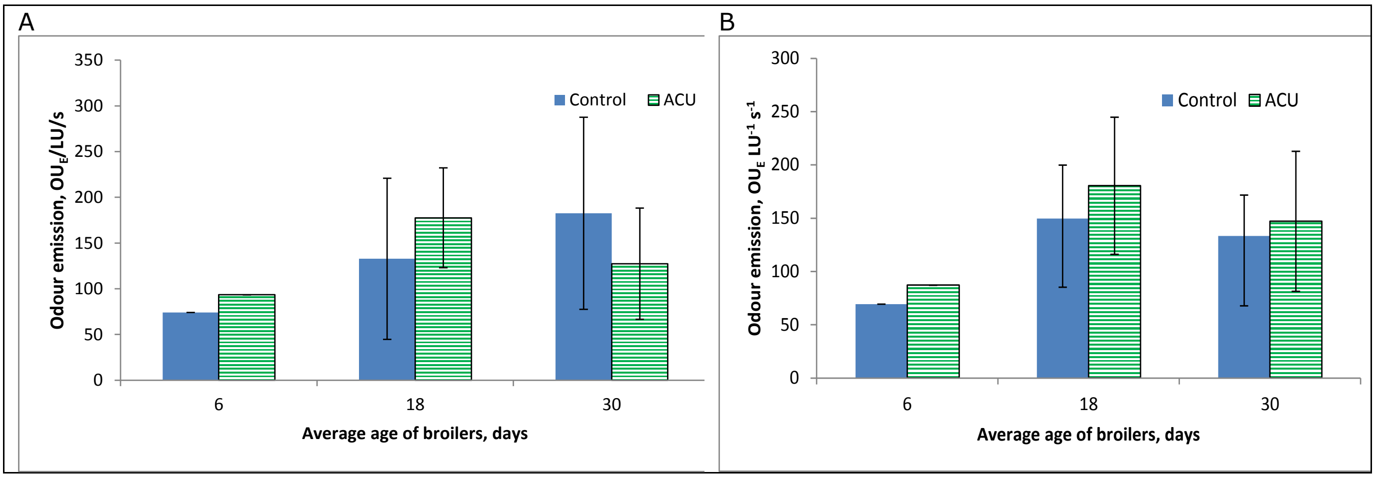


Figure 7. Mean odour emission from broilers produced in broiler houses with the heat exchange system (ACU) and without use of heat exchange system (control). The emission is show at broiler age 6, 18 and 30 days measured at farm 1 (A) and farm 2 (B). The emission is shown as odour emission in odour units (OUE) per livestock unit (LU=500 kg broiler) per second. Error bars indicate standard deviation.

The odour emission per 500 kg body mass of broilers was found to vary between 74 and 182 odour units per second. The odour emission was slightly higher from broiler houses attached the ACU heat exchange system when broilers were 6 and 18 days old and slightly lower when broilers were 30 days old. However significant differences between the average odour emission from broiler houses with and without attachment of the ACU unit were not found (Table 13).

Table 13. Mean odour emission per LU per second from control and ACU test sections at test farm 1 and 2 at the different growth stages, and weighted median and mean±95% confidence intervals (CI). The odour emission is given as OU_E per LU (LU=500 kg broiler) per second. Means followed by same letter do not differ significantly.

Broiler growth stage	Farm 1, OU_E LU^{-1} s^{-1}		Farm 2, OU_E LU^{-1} s^{-1}	
	Control	ACU	Control	ACU
1	74.0	93.4	69.4	87.1
2	132.8	177.5	149.6	180.4
3	182.6	127.4	133.4	147.0
Median	123.7	137.4	120.7	126.9
Mean±95% CI	150.3^a±77.1	142.0^a±49.0	123.3^a±34.5	145.6^a±49.4

Test for difference between Farm 1 con and Farm 1 ACU, p=0.83
Test for difference between Farm 2 con and Farm 2 ACU p=0.16
Test for difference between control Farm 1 and control farm 2 p=0.44
Test for difference between ACU Farm 1 and ACU farm 2 p=0.90

4.2.1 Odour emission, all sampling periods

The average odour emission per livestock unit (LU=500 kg) for the control and ACU test houses were calculated for both test farms. As the odour emissions measured at the two test farms were not found to be statistically different (Table 13), the odour emission data from the two farms were pooled before further analysed. The average odour emission from broiler houses with the heat exchange system (ACU) and without the heat exchange system (Control) can be seen in Table 14.

Table 14. Median and mean odour emission from broiler houses with (ACU) and without (control) a heat exchange system when all sampling periods were included and growth stages are included. The odour emission is given as OU_E per LU (LU=500 kg broiler) per second. Mean values are given as mean ± 95% confidence intervals (CI). Means followed by same letter do not differ significantly (p=0.73)

Technology	No of sampling periods	Median odour emission, OU_E LU^{-1} s^{-1}	Odour emission, OU_E LU^{-1} s^{-1}
Control	17	122.7	136.0^{a}±36,1
ACU	17	132.0	143.9^{a}±30.7
Technology effect, %			-5.8

The odour emission from the control and ACU broiler houses did not differ significantly; however, a slightly higher odour emission was observed from the broiler houses attached the ACU unit. This may be due the higher internal ventilation in the ACU broiler houses causing a higher transport of odour from the litter mat to air outlets.

4.2.2 Odour emission during the summer period

Odour emission factors from husbandry production are in Denmark based on odour emission studies performed at summer conditions. Table 15 summaries the mean odour emission from the odour sampling periods taking place in the summer period running from May to September (Table 7). The mean odour emission during the summer periods was not significantly different to the mean odour emission during the full year.

The use of the ACU unit during the summer period was not found to have a significant effect on odour emission (p=0.81). However, a 5 % non-significant lower mean odour emission was observed from the broiler houses attached the ACU unit (Table 15). The reduced odour emission may be due the fact that broiler litter in general is less humid in the summer period, which may cause a more efficient litter drying effect of the heat exchange system.

Table 15. Median and mean odour emission from broiler houses with (ACU) and without (control) a heat exchange system during the summer period. Mean values are given as mean ± 95% confidence intervals (CI). Means followed by same letter do not differ significantly (p=0.81). One livestock unit (LU) is equal to 500 kg broiler.

Technology	No of sampling periods	Median odour emission, OU_E LU^{-1} s^{-1}	Mean odour emission, OU_E LU^{-1} s^{-1}
Control	11	123.8	145.7^{a}±55.8
ACU	11	116.2	138.2^{a}±41.7
Technology effect, %			5.2

4.2.3 Odour emission at maximal odour emission (growth stage 3)

As illustrated by Figure 7 the mean odour emission per mass of broilers was found to be relatively independent of the size of broilers. However, as the mass of broilers is much higher in the last part of the production period, the majority of the odour emission takes place when the ventilation requirement and manure production is at the highest (growth stage 3).

The mean odour emission observed in growth stage 3 is summarised in Table 16. The mean odour emission from this growth stage did not deviate significantly from the mean odour emission from the odour emission observed when all growth stages were included (Table 14). However, the odour reduction effect of the ACU unit was different. The use of the ACU unit was not found to have a significant effect on odour emission (p=0.66); however, a 10% lower mean odour emission was observed from the broiler houses attached the ACU unit. This difference of technology effect is considered to be caused by the fact that the use of the ACU unit was found to increase the odour emission when the ventilation requirement is low (growth stage 1 and 2) due the higher internal ventilation involved by this system (Figure 7), while the internal ventilation has less influence when the ventilation requirement is increased late in the broiler production period (growth stage 3).

Table 16. Odour emission from large broilers (growth stage 3). Number of sampling periods and median and mean odour emission from broiler houses with a heat exchange system (ACU) and without the heat exchange system (control). Mean values are given as mean ± 95% confidence intervals (CI). Means followed by same letter do not differ significantly (p=0.66).

Technology	No of sampling periods	Median odour emission, OU_E LU^{-1} s^{-1}	Odour emission, OU_E LU^{-1} s^{-1}
Control	9	124.7	147.1^a±59.4
ACU	9	126.9	132.4^a±45.9
Technology effect, %			9.9

4.3 Ammonia emission

The ammonia emission from the control and ACU broiler houses at the two test farms were measured at six measurement periods taking place at growth stage 1 (1 – 11 day old broilers), growth stage 2 (12 – 23 day old broilers), and growth stage 3 (24 – 34 day old broilers). The results at the individual measurement periods are summarised in Figure 8.

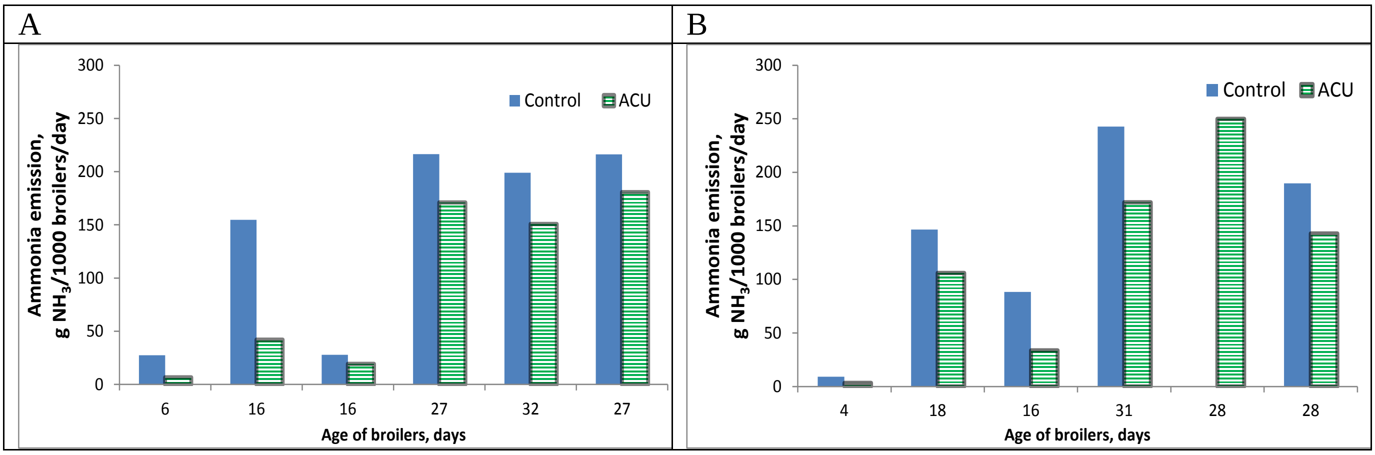


Figure 8. Measured daily ammonia emission per 1000 broilers housed in broiler houses without an ACU heat exchange unit (control) and broiler houses with an ACU heat exchanger attached (ACU). Results are shown for test farm 1 (A) and test farm 2 (B).

Lower ammonia emission was observed from the broiler houses attached an ACU heat exchange system. The ammonia reduction effect of the heat exchange system was found to be highest during growth stage 1 and 2 (Figure 8).

Sampling dates, number of broilers, ventilation rate and climatic parameters are summarised in Table 17 and Table 18.

Table 17. Measured ammonia emission from the broiler house without (Con) and with attachment of the heat exchange system (ACU) at the different sampling periods at test farm 1. One livestock unit (LU) is equal to 500 kg broiler.

Test period	Treatment	Sampling date, *dd-mm-yy*	No of broilers	Age of broilers, *Days*	Mean NH_3 concentration, ppm				Outdoor temperature °C	Indoor air temperature °C	Ventilation rate, m^3 h^{-1}	*Ammonia emission, g NH_3 LU^{-1} day^{-1}*	Ammonia emission, g NH_3/1000 broilers/day
					Ridge	*ACU-in*	*ACU-out*	*Back*					
1	Con	28-8-2012	30,594	8	3.4	ND	ND	0.8	16.4	31.9	21,042	86.0	27.3
	ACU	28-8-2012	29,850	8	1.1	1.5	1.3	0.8	16.4	28.7	17,214	21.2	6.7
2	Con	21-10-12	31,639	16	14.9	ND	ND	1.8	7.8	28.2	20,130	124.0	154.7
	ACU	21-10-12	31,624	16	5.5	6.1	6.0	1.8	7.8	28.2	17,561	33.8	42.2
5	Con	3-6-2015	26,125	16	2.7	ND	ND	0.8	11.7	27.8	25,553	23.4	27.9
	ACU	3-6-2015	26,158	16	1.9	2.4	2.5	0.8	11.7	26.0	18,010	16.4	19.5
3	Con	19-12-12	30,303	27	14.4	ND	ND	1.2	1.9	22.3	28,145	76.1	216.5
	ACU	19-12-12	30,180	27	12.4	13.9	ND	1.2	1.9	22.2	24,346	60.2	171.2
4	Con	21-3-15	31,335	32	13.3	ND	ND	1.1	5.1	22.2	27,874	53.2	199.0
	ACU	21-3-15	30,888	32	11.0	9.9	10.0	1.1	5.1	20.5	31,110	40.3	150.8
6	Con	14-6-15	26,125	27	8.8	ND	ND	2.0	12.2	23.4	51,805	69.8	216.3
	ACU	14-6-15	25,983	27	7.6	9.6	ND	2.0	12.2	22.2	46,963	58.4	180.9

Table 18. Measured ammonia emission from the broiler house without (Con) and with attachment of the heat exchange system (ACU) at the different sampling periods at test farm 2. One livestock unit (LU) is equal to 500 kg broiler.

Test period	Treatment	Sampling date, dd-mm-yy	No of broilers	Age of broilers, Days	Mean NH_3 concentration, ppm				Outdoor temperature °C	Indoor air temperature °C	Ventilation rate, m^3 h^{-1}	Ammonia emission, g NH_3 LU^{-1} day^{-1}	Ammonia emission, g NH_3/1000 broilers/day
					Ridge	*ACU-in*	*ACU-out*	*Back*					
3	Con	14-03-2015	31,881	4	3.6	ND	ND	0.6	1.6	31.3	5,371	32.1	9.0
	ACU	14-03-2015	32,188	4	1.5	1.6	1.6	0.6	1.6	31.6	5,852	11.5	3.2
5	Con	10-08-2015	31,765	18	6.8	ND	ND	1.5	17.4	26.7	48,538	87.1	146.6
	ACU	10-08-2015	31,065	18	5.5	6.7	6.5	1.5	17.4	27.4	44,763	63.0	106.0
1	Con	09-10-2014	36,084	16	5.8	ND	ND	1.3	13.2	27.2	20,478	39.9	45.2
	ACU	09-10-2014	35,420	16	3.8	4.1	4.2	1.3	13.2	28.4	21,993	29.7	33.6
2	Con	03-12-2014	36,953	31	7.2	ND	ND	1.7	3.0	21.9	92,135	76.1	242.8
	ACU	03-12-2014	36,410	31	6.6	6.5	6.2	1.7	3.0	22.1	72,085	53.8	171.9
4	Con	19-05-2015	30,982	28	5.8	ND	ND	2.0	9.0	11.5	ND	ND	ND
	ACU	19-05-2015	31,671	28	11.2	12.1	ND	2.0	9.0	11.5	50,537	78.1	249.9
6	Con	20-08-2015	31,612	28	3.6	ND	ND	1.4	18.1	22.2	167,968	68.9	189.6
	ACU	20-08-2015	30,899	28	3.1	3.6	ND	1.4	18.1	23.2	152,318	51.9	142.8

The measured emission results were average for the different broiler growth stages to give the mean ammonia emission from different broiler growth stages in broiler houses with and without attachment of the ACU heat exchange system (Figure 9).

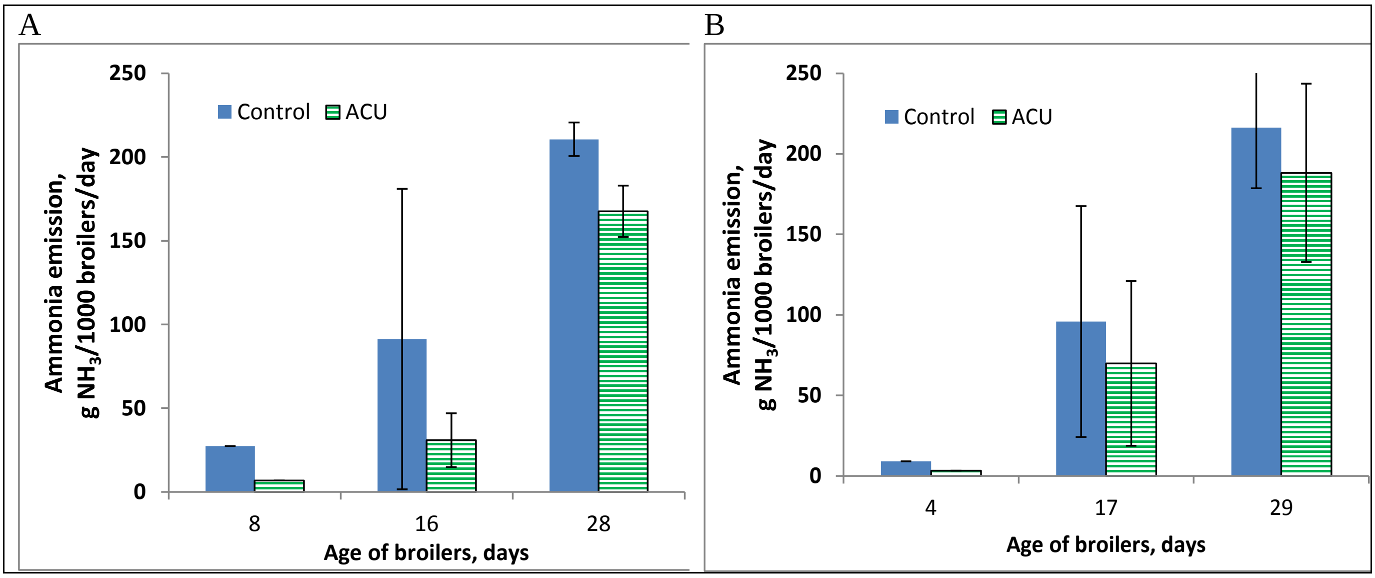


Figure 9. Mean ammonia emission from broiler houses with the heat exchange system (ACU) and without the heat exchange system (control) at different broiler growth stages. Results are shown for test farm 1 (A) and test farm 2 (B). Standard deviation is indicated by error bars.

The ammonia emission from the control and ACU test sections at the two test farms can be seen in Table 19. The emission was positively correlated with broiler age.

Table 19. Comparison of ammonia emission from the different growth stages at the two test farm. Means followed by same letter in the same line are not significant different. Standard deviation is shown in brackets.

Technology	Units	Growth stage 1[1]		Growth stage 2			Growth stage 3		
		Farm 1	Farm 2	Farm 1	Farm 2	P value	Farm 1	Farm 2	P value
Control	g NH_3/1000 broilers/day	27.3	9.0	91.3^{a} (89.7)	95.9^{a} (71.7)	0.74	210.6^{b} (10.0)	216.2^{b} (37.6)	0.81
ACU	g NH_3/1000 broilers/day	6.7	3.2	30.9^{a} (16.0)	69.8^{a} (51.2)	0.21	167.6^{b} (37.6)	188.2^{b} (55.4)	0.57

1. No statistical analyses performed due difference in broiler age and low number of samplings periods

Ammonia results obtained at the two test farms did not differ significantly (Table 19). The emission results obtained at the two farms were therefore pooled in subsequent analyses.

4.3.1 Technology efficiency of the heat exchange system

The ammonia reduction efficiency of the heat exchange system depended on the broiler growth stage. The ammonia emission was found to be significantly lower from broiler houses with a heat exchange system attached when the broilers were young and medium aged (Figure 10). A minor non-significant ammonia reduction was observed from broiler houses attached the heat exchange systems when the broilers were 29 days old.

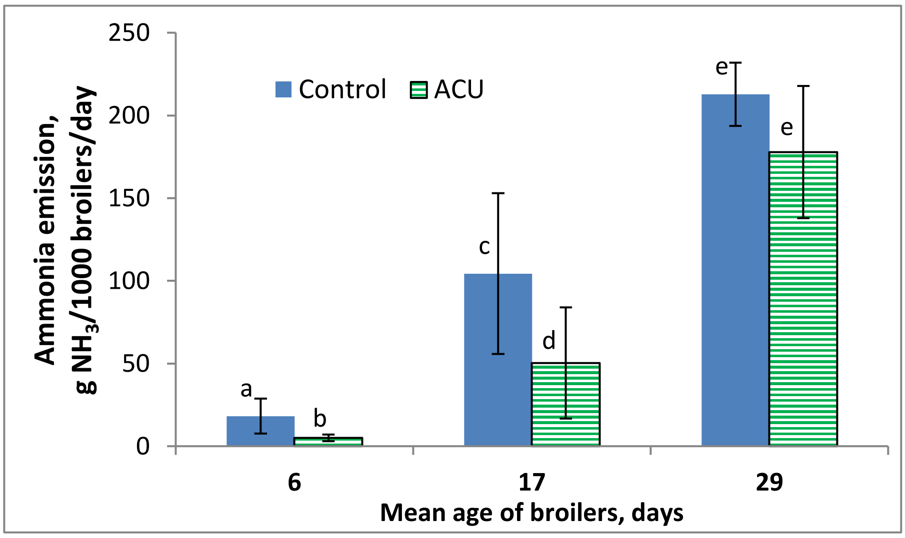


Figure 10. Mean ammonia emission from broiler houses with (ACU) and without (Control) a heat exchange system. Results are shown for young broilers (six days old), medium age broilers (17 days old), and old broilers (29 days old). 95% Confidence Intervals are indicated by error bars. Results indicated by same letters do not differ significantly.

Lower moisture content in broiler houses has been found to reduce ammonia emission (Weaver and meijerhof, 1991; Liu et al., 2007). This study found lower average air moisture content in the broiler houses attached the heat exchange system than in the broiler house without the heat exchange system. The ammonia reduction effect of the heat exchange system is therefore considered to be caused by the drying impact of the higher internal ventilation caused by the vertical circulation fans, and the lower air humidity in broiler houses attached the ACU heat exchange system (

Table 9 and Table 10).
However, also the reduced use of natural gas to heat the broiler house and thereby lower input of combustion vapor may have caused lower air humidity inside the broiler house partly heated by the heat exchange system.

A Danish study of the energy requirement of broiler houses with and without use of heat exchange system has found that the use of the ACU heat exchange system reduces the combustion heat input from 2.16 KWh to 0.42 KWh $broiler^{-1}$ (Energi Nord, 2012). The study found that the requested use of natural gas for heating a broiler house with approximately 30,000 broilers was reduced from 5,800 to 1,130 m^3 gas. The lower incineration of natural gas reduced the total input of 3,064 kg natural gas, which reduces the input of combustion vapor by 6,893 kg per broiler house, if the combustion of the natural gas takes place inside the broiler house. The lower input of combustion vapor therefore reduces the air humidity in the broiler house.
However, the air humidity is also reduced, because the heat exchange system introduces heated air during the full production cycle, while the introduction of combustion heat typically stops when the broilers no longer require heating a couple of weeks after the introduction of new broilers.

The reduction of air humidity is important of several reasons. A lower air humidity causes a faster drying of excreted broiler faeces and thereby a lowering of conversion of its content of uric acid into ammonium, which may be lost as ammonia (Liu et al., 2007). Likewise, the incidence of ammonia burns has been found to be correlated with air humidity causing a lower incidence of foot pad problems (pododermatitis) and thereby improved animal welfare (Weaver and Meijerhof, 1991). However, lowering of the air humidity also influences the ventilation rate of broiler houses, as the ventilation of broiler houses is regulated by the in-house temperature, CO2 and air humidity. The reason for including the air humidity as a parameter for ventilation rate is that a higher dryness of the litter is important for reduction of incidence of paw ammonia burns (pododermatitis) which both reduces the animal welfare (Weaver and Meijerhof, 1991) and the value of produced broilers. A higher air humidity in broiler houses without use of heat exchange system, therefore cause a higher ventilation rate. This was also found in this study, where a higher ventilation rate was observed in test houses without use of the ACU heat exchange system (Table 17 and Table 18).

Higher efficiency of the heat exchange system was observed in the first part of the production period. The reason for the higher efficiency in these periods is considered to be that the majority of the inlet and outlet of air passes through the heat exchange system in the first part of the production period when the ventilation requirement is low, while only a minor fraction of the total ventilation passes through the roof ridge ventilation system when the ventilation requirement is increased in the last part the production period. The fraction of ventilation air passing through the heat exchange system during a full production period can be seen in Figure 11.

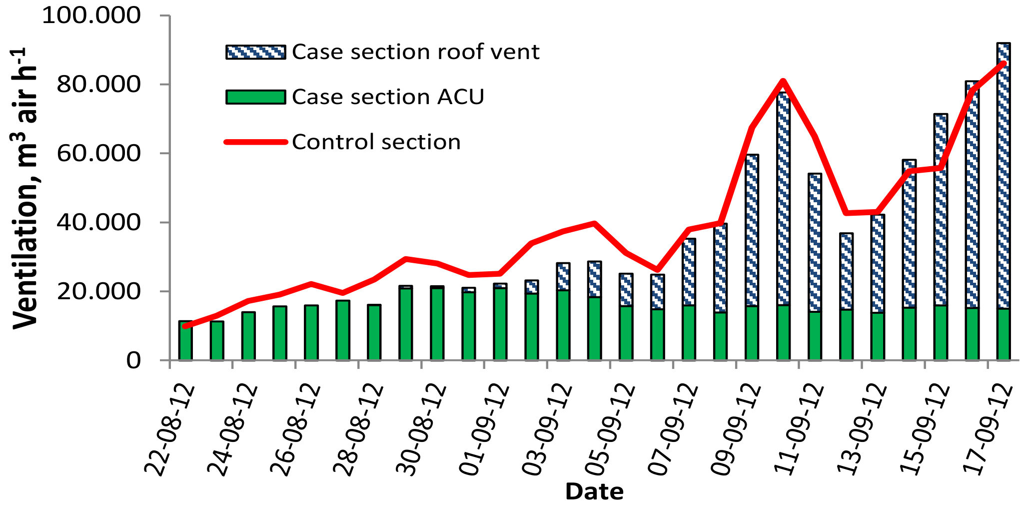


Figure 11. Measured ventilation through the heat exchange system (ACU) and the roof ridge ventilation system in the control and ACU (case) broiler house during the production period.

The average measured ammonia emission for the different growth stages and statistically analyses of differences between control and ACU broiler houses can be seen in Table 20.

Table 20. Measured ammonia emission from small, medium and large broilers housed in broiler houses with (ACU) and without (Control) heat exchange system. Results are show as median and mean values ±95% Confidence Intervals. Mean values followed by same letter do not differ significantly.

Growth stage	Technology	Mean broiler age, days	Ammonia emission, g NH_3/1000 broilers/day	
			Median	Mean
Growth stage 1	Control	6	18.2	18.2^{a} ±10.5
	ACU	6	5.0	5.0^{b} ±2.0
				P = 0.01
Growth stage 2	Control	17	93.6	$93,6^{c}$ ±46.4
	ACU	17	37.9	50.3^{d} ±33.7
				P = 0.04
Growth stage 3	Control	29	216.2	213^{e} ±19.1
	ACU	29	171.6	178^{e} ±39.9
				P = 0.07

The total ammonia emission from broilers produced in broiler houses with and without use of the ACU heat exchange system can be seen in Table 21. Given a broiler production period of 34 days the use of the heat exchange system was found to reduce the ammonia emission by 28 percent. Assuming a cleaning/preparation period of eight days between production periods, a production period of 34 days allows 8.7 production periods per year. The annual ammonia emission per animal place for such a production system can be seen in Table 21.

Table 21. Total ammonia emission from broilers produced in broiler houses with (ACU) and without (Control) use of the ACU heat exchange system. The total ammonia emission was calculated for a broiler production with a production period of 34 days. Means followed by different letter in the same line differ significantly (p<0.05). Standard deviation is shown in brackets.

Total ammonia emission	Length of production period, days	Total ammonia emission			Ammonia reduction efficiency of the ACU system, %
		Control	ACU	P value	
Per production period, g NH_3 broiler^{-1}	34	3.78^{a} (2.7)	2.74^{b} (2.6)	0.04	27.5
Per animal place, g NH_3 animal place^{-1} year^{-1} (8.7 production periods year^{-1})	34	32.9 ^{a} (23.9)	23.8 ^{b} (22.2)	0.04	27.5

The average ammonia emission from broiler houses attached the ACU system was found to be 23.8 g NH_3 year^{-1} animal place^{-1}. This is in accordance to results found by Hensen et al. (2010) who found an annual loss of 20 g NH_3 per animal place in a Dutch study performed at four broiler houses attached ACU systems. The ammonia emission in another Dutch study found average ammonia emission equal to 35 g NH_3 animal place^{-1} year^{-1} from broilers brought up in broiler houses without attachment of the ACU unit (RAV list, 2013). Comparing the ammonia emission from broilers brought up in broiler houses with and without attachment of ACU heat exchange system in Holland gave technology efficiency equal to levels found by the present study.

4.3.2 Deviation to the test protocol and test plan

A number of deviations to the test protocol and test plan were requested. These are listed in the following.

1. Determination of the technology effect on dust emission. Dust is one of the primary performance test parameters of the test protocol; however, according to the test protocol a test can be designed to test the primary target parameter of the technology e.g. an ammonia reducing technology, thereby omitting testing of the other primary parameters. However, this is only possible if it can be ensured that the technology in all probability does not have any negative effect on the non-tested parameters (VERA, 2011 page 6). The technology tested was judged to have no negative effect on the emission of dust from broiler houses. This judgement was based on a preliminary dust study performed by the test institute LUFA Nord-West that found reduced levels of dust from broiler houses attached a heat exchange system. This study, performed on behalf of the technology producer Big Dutchman, found that the use of a heat exchange system (Earny) reduced the dust emission from broiler houses by between 11 to 28% (Big Dutchman, 2014). Therefore, as the dust emission was judged to be unaffected or reduced by use of the technology tested, dust was not included as a parameter in the test.

2. Definition of summer condition. Summer condition is the test protocol defined to be temperature higher than 16˚C. However, in this study summer condition was defined to be the period May to September. The reason for the deviation is that according to the test protocol six odour sampling periods per test farm are requested during the summer period. As a full broiler production cycle was about 1.4 month (cleaning and preparation included) it was decided that the six summer odour sampling periods should be equally divided to the three production periods taking place in the period between May and September.

3. Postponement of odour and ammonia sampling periods. Due technical problems regarding ventilation measurement, the scheduled odour sampling at test farm 1 in November 2014 was postponed to February 2015. Due technical problems regarding ventilation measurement the scheduled odour and ammonia sampling periods at test farm 2 in June had to be postponed to the next production period in August.

4. Forced ventilation. When odour and ammonia sampling were performed at growth stage 1 (small broilers) the ventilation requirement was at the minimum due the low ventilation requirement and the high temperature requirement of the broilers. During this period the ventilation level of the control houses were too low to ensure the requested quantification of ventilation level. During these sampling periods

the ventilation was manually increased to allow detection and to ensure same level of ventilation in control and ACU broiler houses.

5. Extension of length of the broiler production periods. Medium May 2015, the length of the broiler production period was requested increased from 34 days to 38 days by the broiler purchasers. Due that the scheduled sampling days had to be slightly changed. Growth stage 1 was in this period increased to 1 to 13 days, growth stage 2 was increased to 14 to 26 days, and growth stage 3 was increased to 27 to 38 days.

6. Loss of air flow data for the ACU system at test farm 1 in July. Due a technical failure the air flow through the heat exchange system was not logged during the odour sampling period taking place in July. As the ACU system was running at its max capacity, the air flow during the ACU system was assumed to be at its max capacity (22.300 m^3 h^{-1})

7. Loss of manure samples sampled during the pre-test period (2012). Manure samples were sampled during the three pre-test periods that took place in the period between autumn-winter 2012. These samples were stored to be analysed together with the manure samples taken during the test period 2014 and 2015. However, due the age of these samples, they were un-intentionally thrown out before analysed.

8. Odour sampling taking place before 9 am. According to the test protocol odour sampling shall take place between 9 am and 4 pm. All odour samplings were performed according to this request except one odour sampling period started 8:50 the 16th of June 2015 (Table 11). As the majority of the odour sampling took place after 9am (8:50 – 9:20), the results of this sampling period was not excluded.

4.4 Product maintenance

The farm managers were responsible for maintenance and repair of the ACU system and the ventilation. Repair and down time periods were logged in prepared log books (9.3).

The heat exchange systems were thoroughly cleaned and maintained between production cycles. This was performed by an external maintaining and cleaning company. During the production cycles the system was set to a pre-programed washing/cleaning system. The washing program was depending on the outdoor climatic conditions normally started when the broilers were about two to three weeks old. Thereafter the heat exchange system was set to run an automatic washing program once or twice daily. The registration of the ACU air flow system was repaired at test farm 1 in July 2015. Apart from that no repair or downtime periods were registered during the test period. As the uptime period of the heat exchange system was not influenced by the failure of registration of the air flow system or by the washing/cleaning system, the uptime factor was equal to 100%.

4.5 Health, safety, and wastes

The use of the ACU unit was not found to imply any health, safety, or waste issues. The ACU units produce small amounts of condensate. This and leakages from the washing process were collected in liquid tanks situated next to the ACU unit before applied as a fertilizer in plant production.

5 DATA MANAGEMENT

Data management including filling and archiving procedures are described in the AgroTech Test Centre Quality Manual (AgroTech. 2009)

5.1 Data storage. transfer and control

Some data were collected and reported at the test site, while other were collected by electronic means at the test site and send via internet to a PC at the AgroTech main office.

Results from external laboratories were sent electronically by email or in paper version by mail. A list of data compilation and storage can be seen in Table 22.

Table 22. Data compilation and storage summary.

Data type	Data media	Data recorder	Recording of data	Data storage
Test plan and test report	Protected pdf-files.	Test responsible	When approved	Files and archives at AgroTech
Data manually recorded at test site	Data recording forms	Test staff at test site	During collection	Files and archives at AgroTech
Calculations	Excel files	Test responsible	After conclusion of data sampling	Files and archives at AgroTech
Analytical reports	Paper / pdf-files	Test responsible	When received	Files and archives at AgroTech

6 ADDITIONAL INFORMATION

6.1 Animal welfare

The technology effect on animal welfare was not part of the test. However, the less humid litter observed in the broiler houses attached the heat exchange system (

Table 9 and Table 10) is known to reduce problems with paw ammonia burns (pododermatitis) which is expected to reduce the animal welfare (Weaver and Meijerhof, 1991). A positive animal welfare effect of the heat exchange system is therefore expected.

6.2 Occupational health and safety

The tested technology was not found to have any occupational health and safety effects.

6.3 Total external environmental impact

Reduced ammonia emission from broiler houses attached a heat exchange system reduces the ammonia emission from the broiler production and thereby the impact of the production to ammonia sensitive natural habitats like forests, heathlands and water habitat. The reduced ammonia emission will slightly increase the nitrogen level in broiler manure and thereby it’s fertilizing value when used in plant production.

6.4 Food safety and chemical regulation

The technology was not found to have any impact on food safety and chemical regulation.

7 CONCLUSION

The Agro Clima Unit (ACU) heat exchange system was developed to reduce the energy requirement of broiler production; however, the system may also influence the emission of ammonia and odour from broilers. The odour and ammonia effect of the heat exchange system was tested by quantifying the emission of odour and ammonia from broiler houses with and without attachment of ACU heat exchange system. The comparison was performed by six ammonia measurement periods and by nine odour measurement periods performed at two test farms over a full year. The odour emission was quantified by olfactometric analyses. The ammonia emission was quantified by use of photo acoustic multigas analyzer (INNOVA).

Use of the ACU system reduced the indoor air humidity. However, the ACU system was not found to have a clear and consistent effect on broiler litter humidity and nitrogen content. This may partly be explained by the problems related to obtain representative manure samples caused by the heterogeneous nature of litter mat in broiler houses.

The ACU heat exchange system was found to reduce the ammonia emission from broiler houses by 28 %. The ammonia reduction effect was found to be high in the beginning of the broiler production period when the major part of the total broiler house ventilation was performed by the ACU system. Late in the production period (growth stage 3) the ammonia effect of the ACU system was found to be low and non-significant.

Use of the ACU system was not found to have significant effect on odour emission from broiler houses. However, a non-significant 5 % odour reduction was observed during the summer period. In the production period causing the highest odour emission (growth stage 3), use of the ACU heat exchange system was found to cause a non-significant 10 % reduction of odour emission.

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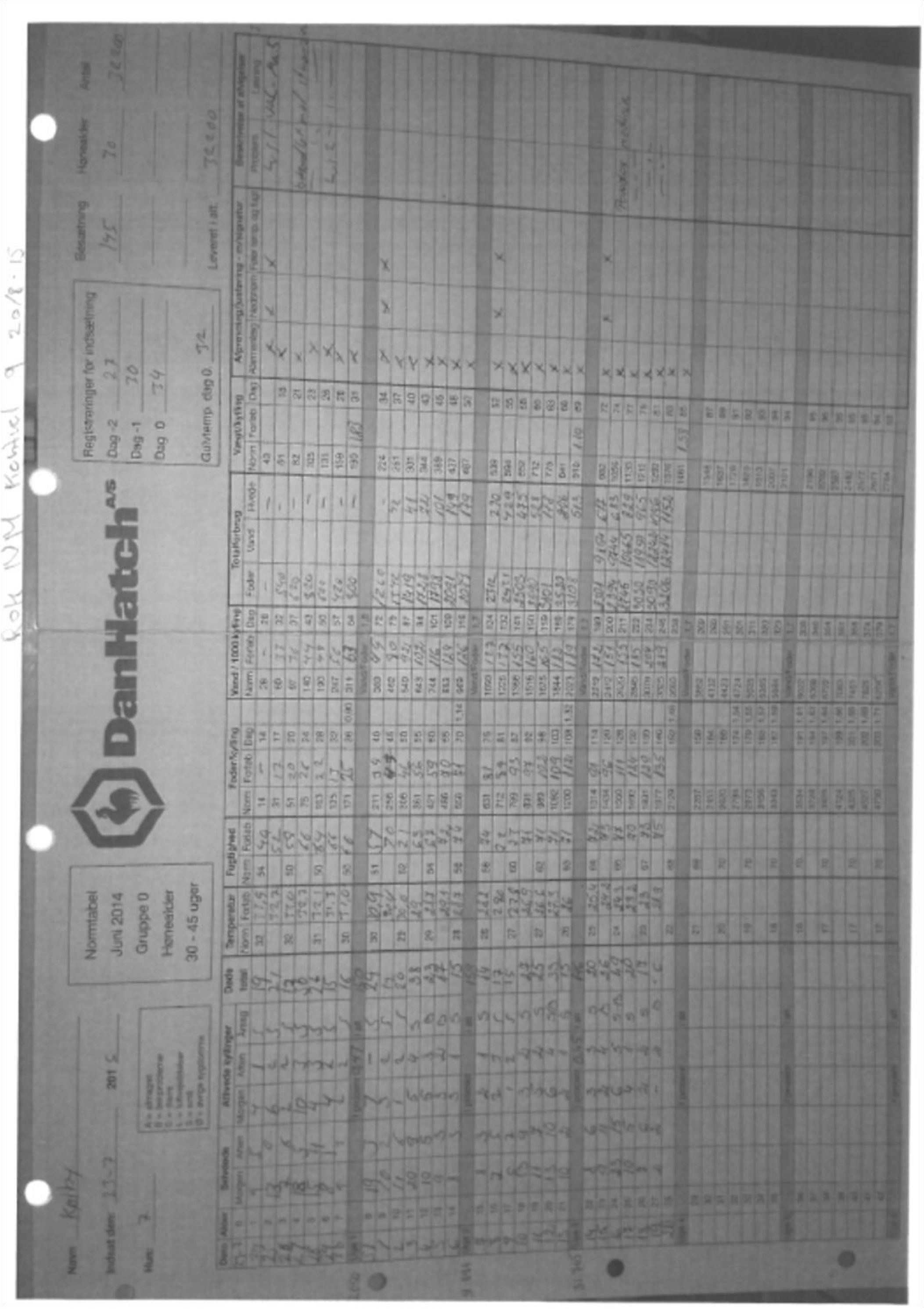
9 APPENDIXES

9.1 Log book Production parameters

Example of production log book for registration of broiler number, growth and performance



9.2 Log book odour sampling (example)

Tider. temperatur og H_2S og NH_3 koncentrationer ved lugt målinger

Udarbejdelse af skema: MNO

Prøveudtager: SPE

Bedrift id: Rokkedahl Nymøllevej 8

Dato: 25.6-15

Udstyrs id

Kit pumpe id	Kitagawa NH3	Kitagawa H2S	Jerome	Temperatur

Sample ID	Målestald	Målested (kip eller FV)	Ude temp ved start sampling	Vacuum kasse id	Start af olfac sam-pling (tt:mm)	Slut af olfac sampling (tt:mm)	NH_3 Kit-konc. ppm	H2S konc. Ppm	Udetemp ved slut sampling	Staldtemp. ved slut sampling	Bemærkninger (eksempelvis sol. skygge. kraftig vind. fejl på ud-styr/opsamling).
10337_MNO_Rok-NM-K-8-a – 5093	Stald 7										
10337_MNO_Rok-NM-K-8-b – 5094	Stald 7										
10337_MNO_Rok-NM-K-8-c - 5095	Stald 7										
10337_MNO_Rok-NM-T-8-a – 5096	Stald 8	Kip									
10337_MNO_Rok-NM-T-8-b – 5097	Stald 8	Kip									
10337_MNO_Rok-NM-T-8-c – 5098	Stald 8	Kip									

Stalden må ikke besøges under udtagningen af luftprøver. Vent med at starte luftindsamlingen til mindst 30 minutter efter at stalden er forladt.

Conditionerede 30 l Nalophan luftposer fyldes på 30 minutter

NH_3 koncentrationen bestemmes med kitagawarør ved udtag fra sugeslange benyttet til lugt umiddelbart efter afslutningen af lugtopsamlingen. Tag min 3 gentagelser fra hver stald

H_2S koncentrationen bestemmes ved brug af Jerome ved udsug i sugeslangeluft eller direkte i staldluft. Husk pumpe og rør. Tag min 3 gentagelser fra hver stald

Husk

- Lugtposer. vacuumkasser. pumper. etiketter. temperaturmåler til stald og udetemperatur. kitagawaudstyr og jerome
- at få kopi eller billede af produktionslogs med antal dyr (evt. opdelt på dyretype. antal døde etc.)
- at gemme/hjemtage/sende Veng/Innnova data for den aktuelle måleperiode

Husk at registrere luftskiftet i løbet af lugtindsamlingen, hvis mekanisk ventilering (Ventilation tjek)

Behandling	Stald id	Tidspunkt	Luftskifte per kip vent. m3/h	Luftskifte veksler. m3/h	Bemærkning
Kontrol	Stald 7			-	
Teknologi	Stald 8				

9.3 Log book. Technology repair and management

Logbog over nedbrud, reparation, service/vedligehold og andre uregelmæssigheder i driften af varmeveksler.

Formålet med logbogen er at fastlægge teknologiens driftssikkerhed og driftstid. Logbogen skal føres af den driftsansvarlige i perioden fra august 2014 til august 2015. Logbogen skal ligge fremme, føres løbende og udleveres til AgroTech når udfyldt, eller ved periodens afslutning.

Bedrift: Rokkedahl Nymøllevej, stald 8

Uregelmæssighed og årsag	Løsning	Tilkald af teknikkere/leverandør (angiv hvem)	Længde af manglende drift (fra til, dato:time)	Indmelder og dato
			Fra: Til:	
			Fra: Til:	
			Fra: Til:	
			Fra: Til:	
			Fra: Til:	
			Fra: Til:	
			Fra: Til:	

9.4 ISO 9001 certification

DS/EN ISO 9001

DNV

DNV BUSINESS ASSURANCE

LEDELSES SYSTEM CERTIFIKAT

Certifikat nr. 124662-2012-AQ-DEN-DANAK

Det bekræftes hermed at

AgroTech A/S

Agro Food Park 15, DK-8200 Aarhus N &
Højbakkegård Allé 30, Klovtofte, DK-2630 Taastrup, Danmark

opfylder kravene i ledelsessystemstandarden for kvalitet:

DS/EN ISO 9001:2008

Dette certifikat er gældende for følgende produkt- eller serviceområder:

Rådgivning, udvikling, test og teknologisk service inden for jordbrug, gartneri, miljøteknologi, bioenergi og fødevarer, herunder udvikling af IKT-løsninger

Sted og dato:
Hellerup, 2012-11-08
DET NORSKE VERITAS,
BUSINESS ASSURANCE, DANMARK A/S

Dette certifikat er gyldigt til:
2015-11-08

DANAK
SYSTEM Reg.nr. 5001

Certificeringsaudit er gennemført under tilsyn af:

Ole Lundis
Lead Auditor

Lars Appel
Adm. direktør

Manglende opfyldelse af betingelser i certificeringskontrakten kan gøre certifikatet ugyldigt.

ACCREDITED UNIT: DET NORSKE VERITAS, BUSINESS ASSURANCE, DANMARK A/S, TUBORG PARKVEJ 8, 2., DK-2900, HELLERUP, DANMARK, TEL +45 39 45 48 00, WWW.DNVBA.COM

9.5 Climatic conditions during sampling periods

Table 23. Mean climatic conditions during odour sampling at test farms.

Test farm	Period id	Date	Radiation, MJ/m^2	Air humid-ity, % RH	Precipation, mm h^{-1}	Wind-speed, m s^{-1}	Winddir, (°)	H_2S conc. ppm
1	HO1	11.09-2014	167,9	87.9	0.0	2.6	52.8	0
1	HO2	10.12-2014	21.6	91.4	0.4	6.6	225.0	0.02
1	HO3	02.02-2015	34.3	90.5	0.1	2.7	53.2	0
1	HO4	19.03-2015	139.5	73.5	0.0	2.5	103.6	0
1	HO5	03.06-2015	107.6	89.6	0.6	7.6	225.0	0
1	HO6	16.06-2015	187.8	69.4	0.0	5.6	45.0	0
1	HO7	21.07-2014	173.1	84.5	0.1	3.8	218.5	0
1	HO8	29.07-2015	168.1	90.3	0.3	3.4	168.7	0
1	HO9	03.09-2015	184.3	83.5	0.1	5.5	225.0	0
2	NMO1	20.08-2014	169.4	85.5	0.3	5.6	217.4	0.03
2	NMO2	11.09-2014	161.6	87.4	0.0	2.5	51.7	0
2	NMO3	09-10-2014	87.5	88.5	0.2	4.7	225.0	0
2	NMO4	04.12-2014	21.5	89.4	0.0	1.2	204.8	0
2	NMO5	24.02-2015	56.8	85.4	0.2	6.6	225.0	0
2	NMO6	07.05-2015	174.0	78.4	0.4	6.4	225.0	0
2	NMO7	20.05-2015	233.8	82.2	0.1	4.3	225.0	0
2	NMO8	12.08-2015	216.6	77.3	0.0	2.7	60.5	0
2	NMO9	20.08-2015	268.9	67.9	0.0	3.7	211.5	0

Table 24. Climatic conditions (24 h mean) during ammonia sampling periods at test farms.

Test farm	Period id	Date	Radiation. MJ/m^2	Air humid-ity. % RH	Precipa-tion. mm h^{-1}	Wind-speed. m s^{-1}	Winddir. (°)
1	H-NH3-1	28.08.2012	ND	ND	ND	ND	ND
1	H-NH3-2	21.10.2012	ND	ND	ND	ND	ND
1	H-NH3-3	19.12.2012	ND	ND	ND	ND	ND
1	H-NH3-4	21.03-2015	49.8	89.5	0.1	5.0	146.0
1	H-NH3-5	03.06.2015	119.8	88.8	0.6	7.6	225.0
1	H-NH3-6	14.06.2015	153.1	86.0	0.6	4.0	59.6
2	NM-NH3-1	09.10.2014	169.4	85.5	0.3	5.6	217
2	NM-NH3-2	03.12.2014	161.6	87.4	0.0	2.5	51.7
2	NM-NH3-3	14.03.2015	87.5	88.5	0.2	4.7	225
2	NM-NH3-4	19.05.2015	21.5	89.4	0.0	1.2	204.8
2	NM-NH3-5	10.08.2015	56.8	85.4	0.2	6.6	225.0
2	NM-NH3-6	20.08.2015	174.0	78.4	0.4	6.4	225.0

9.6 Registration form for control of equality between ventilation rate and gas concentrations of ridge ventilation ducts

Example of data sheet used for data collection during sampling

Ventilationsydelsesbestemmelse slagtekyllingehuse kipventilatorer

Bedrift: Haubro	Dato:	Ventilator id (navn og type):
Stald:	Udetemperatur:	Ventilator diam:
Antal kip ventilatorer:	Stald temperatur:	Max air capacity, (ved Pa):
Evt. varmevekslervent (j/n):	Vindhastighed:	Styresystem:
Evt. gavlventilatorer i brug (j/n):	Vent målevinge id (type, diam):	
Prøvetager:	Bemærkninger:	

Søgt andel max vent, %	Tidspunkt, tt:mm	Målt andel max vent, %	Vent Rok, m3/h	Vent målevinge, m3/h	Bemærkning
Min vent					
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					

Kontrol af gaskoncentration og ventilationsflow for kipventilationsafkasts på slagtekyllingestalde.

CO_2 og NH3 koncentration målt centralt i afkasts ved kitagawa gas detection tubes.

Kitagawabestemmelse

Bedrift:	Dato:
Stald:	Prøvetager:
Bemærkninger:	

Afkastnummer kip (1 tættetest på kontrolrum)	CO_2 koncentration, ppm	NH3 koncentration, ppm	Målt ventilation m^3 h^{-1}	Bemærkning
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				

9.7 Control of equality between ventilation rate and gas concentrations of ridge ventilation ducts

Example of data from test farm 1

Kontrol af ventilationsrate og concentrationer i afkast på Rokkedahl teststalde									
Nymølleve	Id:	NM 9-1							
Dato:	01-nov-15								
Luftflow målt ved		Testo anem	Average of samples taken 0.4 m below top of ducts						
Flowmålinger og gasbestemmelse gennemført i afkast 7 på alle teststalde									
Flowbeste	06-11-2015	06-11-2015	Gas koncentrations			Gas koncentrations		
Afkast 1 er tættest på kontrolrum			CO2			NH3		
Stald	8	7	Stald	8	7	Stald	8	7
	Luftflow	Luftflow		ppm	ppm		ppm	ppm
Afkast	NM, tek	NM con	Afkast	NM, tek	NM con	Afkast	NM, tek	NM con
1	2250	250	1	800	800	1	3,3	3,3
2	2300	240	2	800	800	2	3,5	2,9
3	2400	230	3	800	810	3	3,2	3,2
4	2400	230	4	750	780	4	3,1	3,1
5	2300	240	5	800	800	5	3,3	3,1
6	2100		6	800		6	3,2	
7	**2200**	**230**	**7**	**750**	**780**	**7**	**3,3**	**3,1**
8	2100	230	8		800	8	3,1	3,3
9	2300	240	9			9	3,2	3,1
10	2400	230	10			10	3,1	2,8
11	2400	240	11			11	3,3	3,2
12	2300	250	12			12	3,6	3,1
13	2200	245	13			13	3,5	3,1
mean	**2281**	**238**	mean	**786**	**796**	mean	**3,3**	**3,1**
Stdev	**107**	**8**	Stdev	**24**	**11**	Stdev	**0,2**	**0,1**
CV, %	**4,7**	**3,3**	CV, %	**3,1**	**1,4**	CV, %	**4,9**	**4,6**

9.8

9.8 Calibration report for the aneomometers used for measurement of ventilation rate in test houses.

Seite 3 von 3	Datei: Protokoll_Stienen.docx DLG-Prüfungs-Nr.: 11-730 Stand: 13.12.2011 10:27:00 Pfeifer © DLG	Teilprojekt: **Ventilatormessung** *-Protokoll-* **„Kalibriermessung"**	DLG-Testzentrum Technik & Betriebsmittel D-64823 Groß-Umstadt Tel. 069 247 88-600 Fax 069 247 88 649 www.dlg-test.de

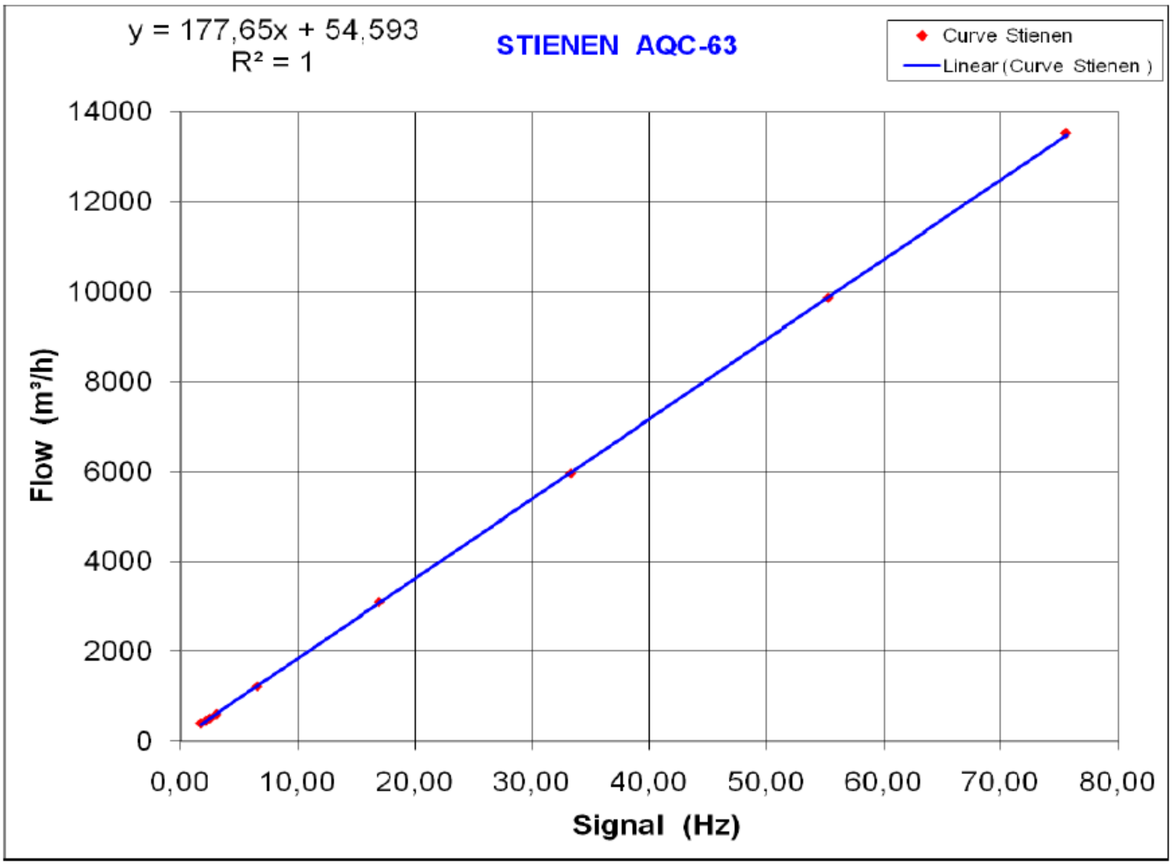
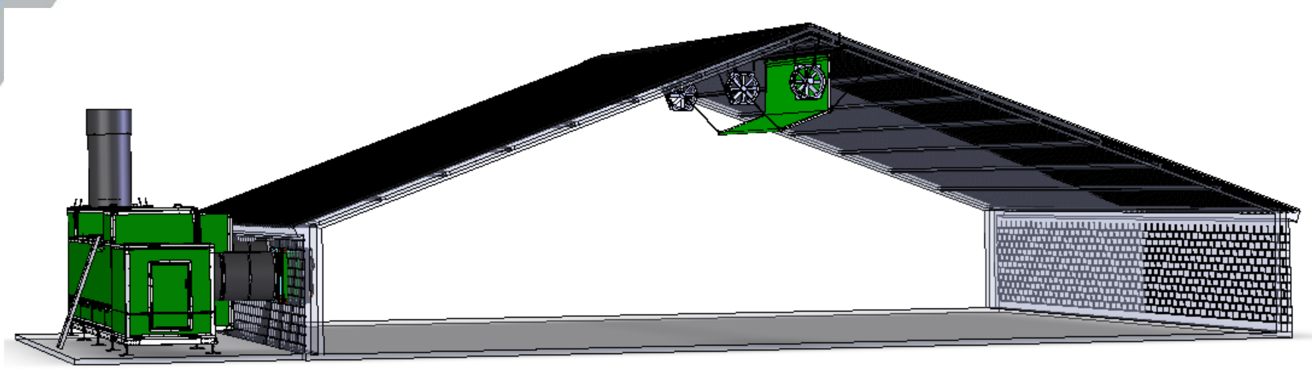


Figure 12. Calibration procedure and results of calibration of the air anemometers (Stienen AQC-63) used in ridge ventilation ducts.

9.9 AgroSupply User manual



USER MANUAL
CLIMA MANAGER

FOR CLIMA^{+} 200 SYSTEM

UM-ACM-1.4-DK / 08-2013

TABLE OF CONTENTS

CHAPTER

INDEX

INTRODUCTION

CAUTION:

This manual must be read by or to each person, before that person operates, cleans, repairs, supervises the operation of, or uses this system in any way.

CAUCION:

Este manual debe ser leido por a cada persona antes de comenzar a operar, limpiar, reparar, supervisar la operación de, o utilizar esta sistema de cualquier manera.

ATTENTION:

Ce manuel doit être lu par, ou a, toute personne avant qu'elle ne mette en route, nettoie, répare, supervise le fonctionnement ou utilise cet système, de quelque manière que ce soit.

VORSICHT:

Jeder, der dieses System bedienen, reinigen, reparieren, überwachen oder auf irgendeine Weise benutzen soll, muß vorher diese Hinweise lesen oder vorgelesen bekommen.

ATTENTIE:

Een ieder, die dit systeem bedient, reinigt, repareert, controleert of op enige andere wijze gebruiken zal, dient vooraf deze bedieningsvoorschriften te lezen.

1. LIABILITY

Agro Supply BV cannot be held responsible for any costs, damage or personal injury if it's system is not used in accordance with the instructions as described in this manual.
The information provided in this manual is valid for the standard design of the system. Parts of your system may differ from this standard design.
Since Agro Supply BV is constantly improving its systems it may be possible that there are small differences between your system and this manual.
Though this manual has been put together with the utmost care, Agro Supply BV cannot accept any responsibility for costs, damage or personal injury arising from any fault and/or incompleteness in the content of this document.

2. GENERAL

This manual contains important information concerning safety, operation, adjustment, maintenance, cleaning and repair of the Agro Supply BV system. For uncomplicated functioning of the system, read this manual carefully and work according to the directions in this manual.
Besides the design and the used materials, also the operation and maintenance have great impact on the functioning, the life span and the operational costs of our system. You, as the owner of the system, are responsible for the execution of maintenance according to the directions and the intervals in this manual.
This manual will help you to gain knowledge to use the system as it should be used: correct operated and excellent maintained.

An Agro Supply BV system meets the demands, mentioned in the European machine guideline (CE).

CE

3. COPYRIGHT

4. GENERAL

This manual contains important information concerning safety, operation, cleaning, maintenance and breakdown remedies.
At all time this manual must be accessible for all personnel working with the system. Keep it in a permanent place, close to the system. When the manual is lost or damaged, order a new copy as soon as possible.
The user of the system should read and understand the total user manual before operating, cleaning, maintaining and repairing the system.
Never change the sequence of procedures as described in this manual.
Besides this manual also knowledge about the installation and adjustments of the system may be helpful for communication with the Agro Supply dealer. This information is described in the English-language installation manual, which is also delivered with this system.

5. SAFETY REGULATIONS

Before starting operation, cleaning, maintaining the system or before remedying breakdowns, first read this chapter and chapter Safety.

6. LEGAL REGULATIONS

- All safety directions stated in this manual must be observed.
- Along with the safety regulations in this chapter, the instructions of the qualified trade organization of your country must be observed to avoid accidents.
- Before starting to repair or maintain the system, always consult your safety manager to discuss if a work permit is required for this job.
- All safety devices in the system and the safety indications mentioned in this manual are conditions to control the system safely. The owner and his qualified personnel are in the end the ones responsible for the safe use of the system.
- The owner is responsible for the ability of the qualified personnel to perform its duties according to the safety measures.
- Technical changes, which influence the safety working of the system, may only be executed after the approval of the service department of Agro Supply.
- Only use genuine Agro Supply parts or CE-certified parts for replacement.
- Agro Supply cannot be held responsible for any consequential damages to the system or other installations that were caused by technical changes, unprofessional maintenance and repairs on our system, which were executed by the customer.
- Warranty becomes invalid when consequential damages to the system, caused by technical changes, unprofessional maintenance and repairs, were executed by the customer.

	DANGER! Failure to obey legal regulations may result in permanent personal injury or death.
	ATTENTION! Failure to obey legal regulations may result in damage to the system.

7. HOW TO USE THIS MANUAL

The manual is constructed to provide a maximum amount of information with a minimum amount of searching. The key to easy reference is the Table of contents. Familiarize yourself with it and you won't have any trouble locating information from any area of system.

8. WHO SHOULD USE THIS MANUAL

Owner:
The owner (contractor, concern) is the person that owns or hires the system and puts this system into production. The owner must take care that the users of the system will read the manual.

Operator:
The operator is the person who operates the system as ordered by the owner.

Professional:
A professional is someone who can assess the duties appointed to him on account of his education, knowledge and experience and who can assess the dangers attached, thereby avoiding these dangers.

Maintenance engineer:
The maintenance engineer is the professional who is deemed qualified by the owner to perform certain duties. The qualification only applies to those assigned duties. The maintenance engineer must read the total manual.

9. MANUAL INFORMATION

System type:	**Clima$^+$ 200** Unit for Broilers
Manual revision:	1.4 (August 2013)
Software version:	V1.14 26/04/2013

10.SERIAL NUMBER

Each system has a unique project- and type number printed on the nameplate, which can be found on the door of the intake ventilator box. Note down this project- and type number to have it available when contacting the Agro Supply service department.

11. SYMBOLS

Symbols are used in the manual when special attention/caution is required while working on the system. The special symbols and their meaning are depicted in the below table.

Symbol:	Meaning:
	**DANGER!** This symbol is used when instructions should be followed to the letter. If not they may result in permanent personal injury or death.
	**CAUTION!** This symbol is used when instructions should be followed to the letter. If not they may result in permanent personal injury.
	**ATTENTION!** This symbol is used when instructions should be followed to the letter. If not they may cause damage to the system.
	**LIVE STOCK!** This symbol is used to advise for the well being of the livestock. Disregarding the advice may cause illness or death of the livestock.
	**TIP!** This symbol is used as a helpful hint to simplify the execution of certain tasks.

12. SAFETY

13. GENERAL

Only persons meeting the following requirements are authorized to work with the system. These persons should be:
- Skilled and specifically trained for their duties.
- Familiar with the contents of this manual.
- Familiar with the locations of the safety devices.
- 18 years old or above.
- Familiar with the national and regional regulations regarding safety.

These persons should have reached the minimum legal age required to perform this work.
These persons are NOT under influence of any drug, medicine or alcoholic drink.

	**DANGER!** Keep children and incompetent persons away from the system!

The system is only to be used for the purpose it was designed for. See the chapter Machine description for details.

14. SAFETY REGULATIONS

- Do not use the system when safety devices have been removed. This system may contain sharp edged parts, moving parts and rotating parts. When protective covers are removed, sharp edges and pinch points may be exposed. Use extreme caution and avoid touching or striking these areas with your hands or body because they may cause injuries.

- Do not enter parts of your body or objects into openings in the system. This may lead to serious physical injury or damage to the system. It can be dangerous to be in, on or under the system while it is operational.

- Do not touch or come near moving or rotating parts. Physical contact with these parts is dangerous.

- Do not work alone on the system. At least one other person should be present.

- Before starting to clean, maintain or inspect the system or before remedying breakdowns, follow the steps mentioned below:
    - Switch off the system and secure it against accidental switching on.
    - Post “Do not switch on” warning sign on the main switch.
    - Make sure that no components are moving.

- Before switching on the machine, you must check the following:
    - All safety devices are in place and are functioning.
    - No other persons are in the system.
    - No tools or objects are in the system.
    - No other persons are at risk.

- Do not use water to clean electricity cabinets.

- Manual activation of safety switches is forbidden.

- When the safety devices are put out of operation, the system must first be switched off and secured against accidental switching on.

- Work inside the electrical cabinet may only be undertaken by skilled personnel like Agro Supply service engineers or its dealers service engineers.

- Always switch off the main switch before opening electrical cabinets.

- After switching off the main switch, parts inside the electrical cabinet remain live for approximately one minute. The frequency inverters may hold a high voltage charge during this time. Do not touch parts inside the electrical cabinet as long as displays of frequency inverters are on.

- Several parts inside the electrical cabinet maintain voltage even when the main switch is turned off (main switch, main power supply, terminals for communication with other systems, etcetera).

	**DANGER!** Failure to obey safety regulations may result in permanent personal injury or death.
	**ATTENTION!** Failure to obey safety regulations may result in damage to the system.

15. SAFETY PROVISIONS

Before operating the system, the safety devices must be checked for correct functioning. Also the protective covers must be mounted before starting to use the system. Repair or replace safety devices before using the system if they do not work properly.
Never rely solely on safety devices. Always switch off the system and lock up the power source (1) before working on the machine.

	DANGER! Protective covers safeguard dangerous system areas. These covers are of utmost importance to operate the system safely. Never operate the system when protective covers are removed because serious injury or death may occur!

16. DEFINITION OF SAFETY DEVICES

Safety devices are: lockable doors (2), safety switches (3) and protective grids (4).

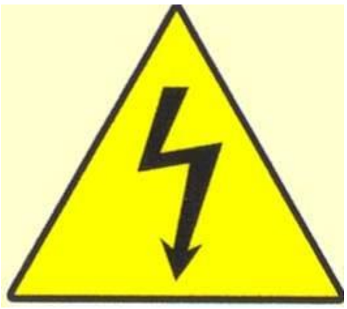
The safety switch stops (a part of) the system immediately when the door is opened.
Protective grids shield off dangerous (moving) parts. These covers cannot be removed without tools.
Lockable doors are doors that can only be opened with a key. The key should only be in possession of a supervisor.

	DANGER! Lockable doors safeguard dangerous system areas. These doors are of utmost importance to operate the system safely. Never operate the system when doors are open or not locked because serious injury or death may occur!

17.WARNING LABELS

The Agro Supply system contains dangerous parts when they contact the body. The following labels are posted as a warning. Understand and remember the meaning of the warning labels.

	**DANGER!** Keep the warning labels clean. When labels become unclear, replace them.



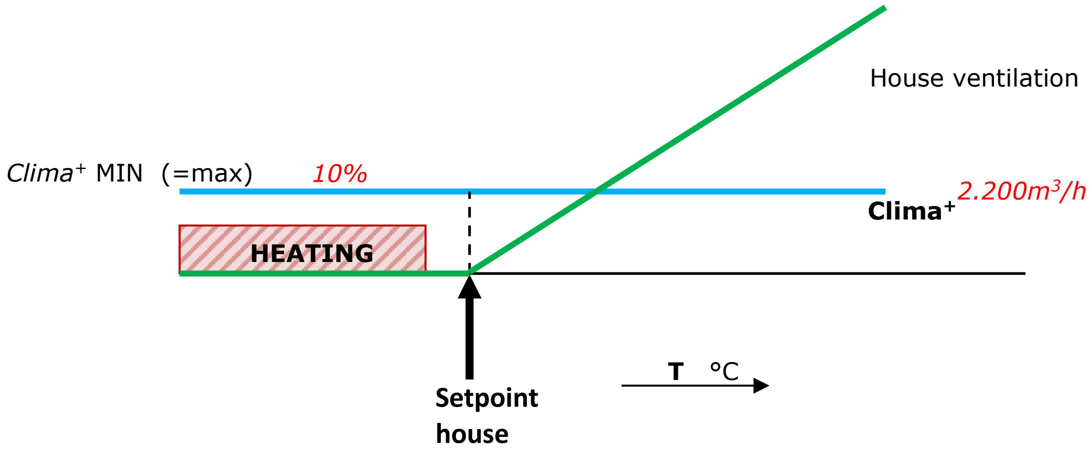
The flashlight label is used to warn for dangerous voltage inside a cabinet. Contacting parts inside this cabinet may result in permanent personal injury or death.

18. SYSTEM PRINCIPLE

The Clima Manager has a number of possibilities to the control the Clima⁺ Unit, here three ways are explained.

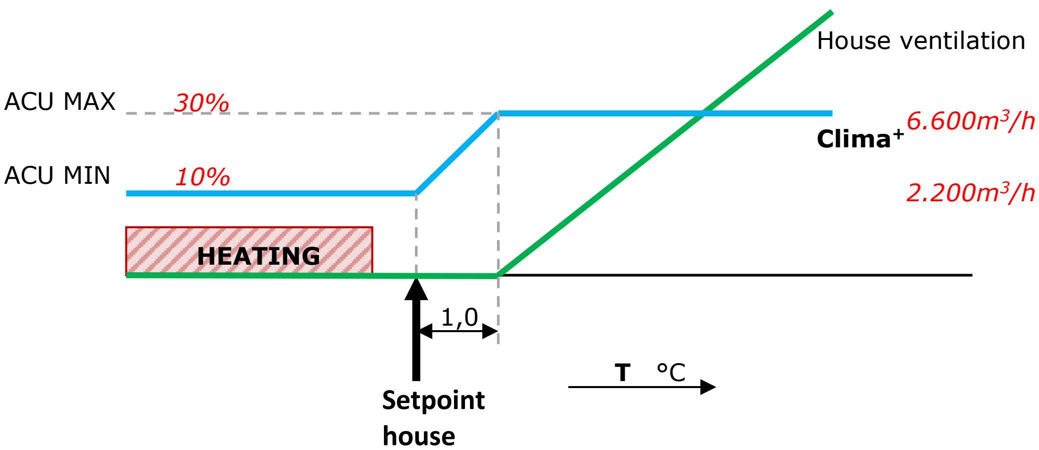
1. Only to provide minimum ventilation, e.g. on a given day is the desired minimum ventilation need in a house 3.000 m3/h, the Clima Manager will manage the Clima⁺ so that at all times this 3.000 m3/h will be ventilated (blue line), regardless of the house temperature. If it would be too hot in the house, the Clima Manager will not responding to that, but should the house ventilation been able to correct this (green line)

[2823] Maximum Curve = MIN
(Clima⁺ is providing ONLY minimum ventilation!)



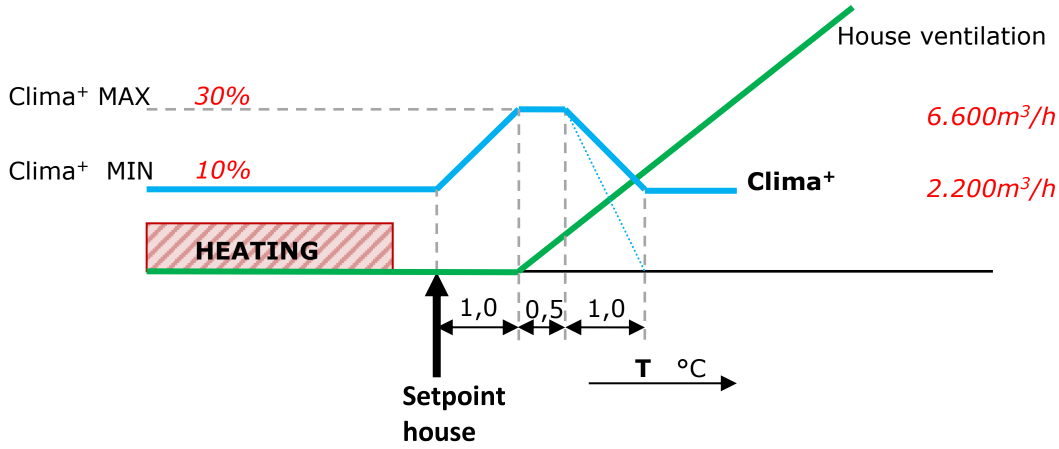
2. 2nd Function of the Clima Manager is again to provide the minimum ventilation, but also to be the first to correct via the Clima⁺ Unit on a higher house temperature: 3.000 m3/h are again ventilated, if the house temperature goes above the target value of the house, the Clima⁺ Unit will ventilate more, but within certain limits, e.g. 6.000 m3/h. should the temperature rise even further, then the house ventilation should start.

[2823] Maximum Curve = ON



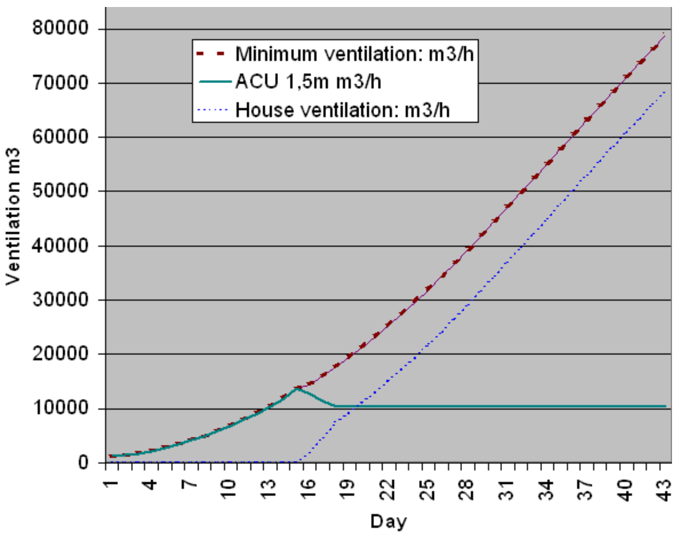
3. The 3rd and last main function of the Clima Manager is to reduce to a set minimum ventilation percentage, if it gets too hot in the house: also here ventilated is with 3.000 m3/h, if it is getting warmer in the house, than the capacity will be increased to 6.000 m3/h. If it gets even warmer, then the house ventilation the ventilation completely will take over and the Clima⁺ Unit is slowed down to 1.000 m3/h in this example.

[2823] Maximum Curve = ON (& reduction = ON)



EXAMPLE: Based on minimum ventilation of 1 m3/h/kg							
		Weight:		Ventilation:			
Day:	Broilers	Broiler:	Total:	Minimum:	ACU 1,5m	House:	ACU setting:
		Kg	Kg	m3/h	m3/h	m3/h	
0	30.000	0,039	1.170	1.170	1.170	0	9%
1	30.000	0,047	1.410	1.410	1.410	0	10%
2	30.000	0,057	1.710	1.710	1.710	0	12%
3	30.000	0,072	2.160	2.160	2.160	0	16%
4	30.000	0,092	2.760	2.760	2.760	0	20%
5	30.000	0,115	3.450	3.450	3.450	0	25%
6	30.000	0,138	4.140	4.140	4.140	0	30%
7	30.000	0,162	4.860	4.860	4.860	0	35%
8	30.000	0,194	5.820	5.820	5.820	0	42%
9	30.000	0,227	6.810	6.810	6.810	0	50%
10	30.000	0,264	7.920	7.920	7.920	0	58%
11	30.000	0,305	9.150	9.150	9.150	0	67%
12	30.000	0,347	10.410	10.410	10.410	0	76%
13	30.000	0,395	11.850	11.850	11.850	0	86%
14	30.000	0,455	13.650	13.650	**13.650**	0	100%
15	30.000	0,480	14.400	14.400	12.604	1.796	92%
16	30.000	0,533	15.990	15.990	11.508	4.482	84%
17	30.000	0,589	17.670	17.670	10.275	7.395	75%
18	30.000	0,648	19.440	19.440	10.275	9.165	75%
19	30.000	0,710	21.300	21.300	10.275	11.025	75%
20	30.000	0,775	23.250	23.250	10.275	12.975	75%
21	30.000	0,843	25.290	25.290	10.275	15.015	75%
22	30.000	0,914	27.420	27.420	10.275	17.145	75%
23	30.000	0,988	29.640	29.640	10.275	19.365	75%
24	30.000	1,065	31.950	31.950	10.275	21.675	75%
25	30.000	1,145	34.350	34.350	10.275	24.075	75%
26	30.000	1,227	36.810	36.810	10.275	26.535	75%
27	30.000	1,311	39.330	39.330	10.275	29.055	75%
28	30.000	1,397	41.910	41.910	10.275	31.635	75%
29	30.000	1,484	44.520	44.520	10.275	34.245	75%
30	30.000	1,572	47.160	47.160	10.275	36.885	75%
31	30.000	1,661	49.830	49.830	10.275	39.555	75%
32	30.000	1,749	52.470	52.470	10.275	42.195	75%
33	30.000	1,838	55.140	55.140	10.275	44.865	75%
34	30.000	1,928	57.840	57.840	10.275	47.565	75%
35	30.000	2,017	60.510	60.510	10.275	50.235	75%
36	30.000	2,106	63.180	63.180	10.275	52.905	75%
37	30.000	2,194	65.820	65.820	10.275	55.545	75%
38	30.000	2,282	68.460	68.460	10.275	58.185	75%
39	30.000	2,370	71.100	71.100	10.275	60.825	75%
40	30.000	2,456	73.680	73.680	10.275	63.405	75%
41	30.000	2,541	76.230	76.230	10.275	65.955	75%
42	30.000	2,626	78.780	78.780	10.275	68.505	75%

EXAMPLE



19.

20. VENTILATION

This chapter describes how to use the Clima Manager to control the Clima⁺ unit according a minimum ventilation curve. Before starting to control the Clima⁺ unit it is important to have basic knowledge about the climate inside a birds house.

The minimum necessary ventilation in a birds house is approximately 1 m³/hour/kilo unless otherwise stated.
By estimating the weight of a bird on a certain day during the cycle and multiplying this with the number of birds in the house, you know the minimum ventilation needed in your house on that day.

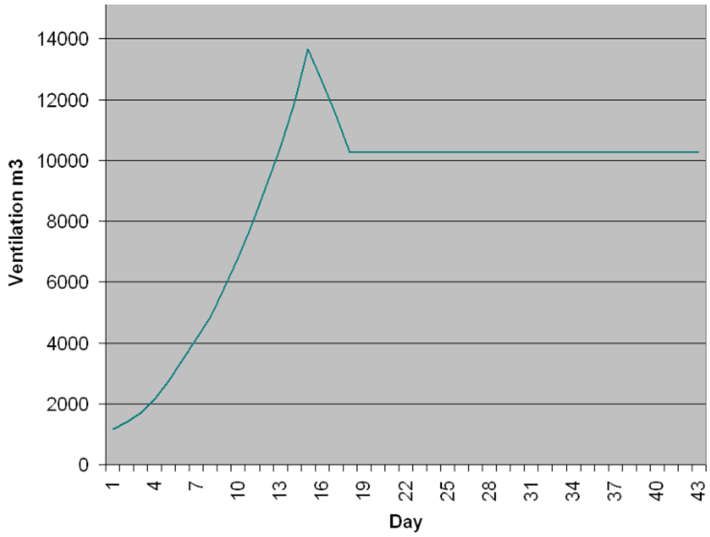
See alongside table and the graphic as a typical example.
The table shows the increasing weight of the birds and thus the increasing need of ventilation. The need of ventilation is visualized in the graphic (minimum ventilation, brown dashed line).

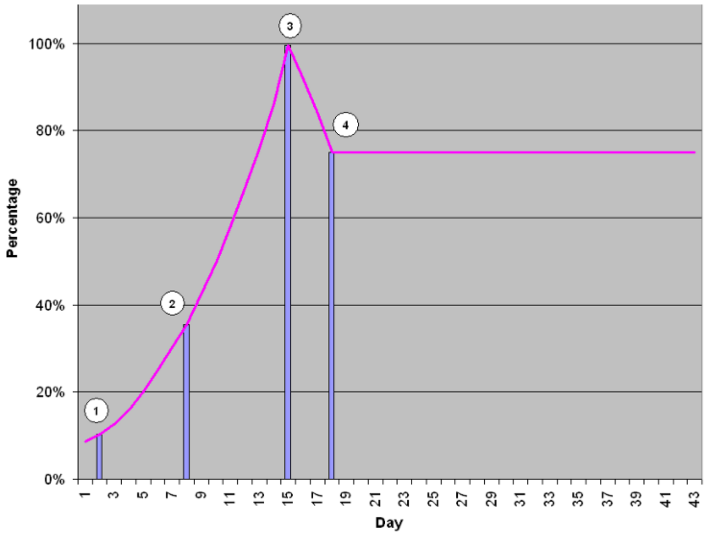
In the alongside table you can see that during the first 2 weeks of the cycle, the Clima⁺ unit supplies all the ventilation, but then it reaches its maximum capacity. This is visualized in the graphic (Clima⁺ 1.5 m, green line).
After this first 2 weeks another ventilation system (the so called normal house ventilation) is necessary to supply the extra ventilation.
See the graphic (house ventilation, blue dotted line).

21. A VENTILATION CURVE

As you can see in the graphic the needed ventilation is a curved line, the so called ventilation curve.
With the Clima Manager it is possible to program this ventilation curve that takes care of (part of) the heating of the house and the correct minimum ventilation during the first days of a new flock.

Before starting to program this ventilation curve, first you need to know the maximum capacity of your heat exchanger:
Clima⁺ 1,0 m   9.400 m³/hour
Clima⁺ 1,5 m   13.700 m³/hour
Clima⁺ 2,0 m   18.400 m³/hour
Clima⁺ 2,5 m   22.300 m³/hour





In the alongside graphic, you can see the necessary ventilation curve for a Clima+ 1,5 m (with a maximum capacity of 13.700 m³/hour) using the example table of the previous page.

The Clima+ unit is able to follow this necessary ventilation curve when 4 breakpoints are programmed.
With the below explanation it is possible to find the 4 breakpoints. (In the Clima Manager, more breakpoints can be programmed if needed).

1st breakpoint:
On the first day of the cycle, you calculate the necessary minimum ventilation and the corresponding fan speed (in % of its maximum).

2nd breakpoint:
On the seventh day of the cycle, you calculate the necessary minimum ventilation and the corresponding fan speed (in % of its maximum).

3rd breakpoint:
With the capacity of your heat exchanger, you can estimate on which day the heat exchanger has to run with a fan speed of 100% to give its maximum ventilation.

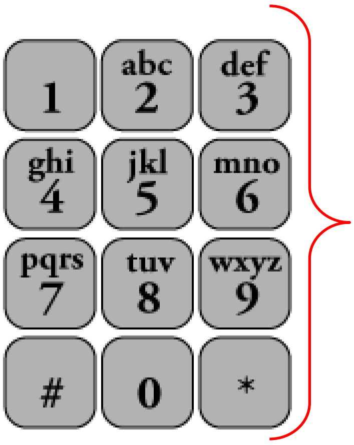
4th breakpoint:
The speed setting of the 4th breakpoint is the constant speed setting used from this breakpoint day until the Clima+ unit is stopped. This breakpoint is a few days after reaching the maximum capacity and its fan speed is approximately 75%. This reduces energy costs.

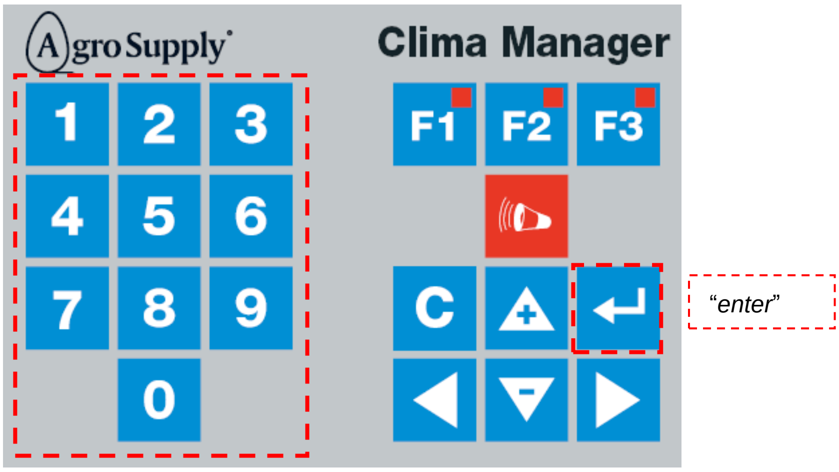
	**LIVE STOCK!** When the Clima+ unit reaches its maximum capacity the normal house ventilation must gradually start to supply fresh air. You may program the minimum setting of the house ventilation to coincide with the capacity of the Clima+ unit. Other settings of the normal house ventilation (temperature, maximum ventilation) remain the same as running without the Clima+ unit.
	**LIVE STOCK!** During days with warm weather, the house temperature may become too high and the normal house ventilation needs to cool the house while the Clima+ unit keeps supplying the minimum ventilation. Therefore it's very important that the normal house ventilation is NOT switched off, but only the minimum ventilation setting is set to 0.

3. OPERATION

22.OPERATION MENU

General
The Clima Manager is provided with an extensive graphic display. The control buttons are located below the display.





With the numerical part values can be changed. There can also be jumped directly to menus. This is only possible when there is a number for a line. Also, some standard texts can be adapted to its own content. The name "time clock 1" might be changed to "water clock". The numeric keys than just are like a (mobile) phone and have also letter values.

By means of the 4 arrow keys you may navigate through the different menus. Navigating can consist of a combination of arrow keys and numeric keypad, just what is taught. To go further in a menu choice, the "enter" key is to be used. Also to change a value, the "enter" key is to be used. If a field is selected, the field is dark: **050**

When after this the "enter" key is pressed, there will be a framework for the first digit: now there are two possibilities: **050**

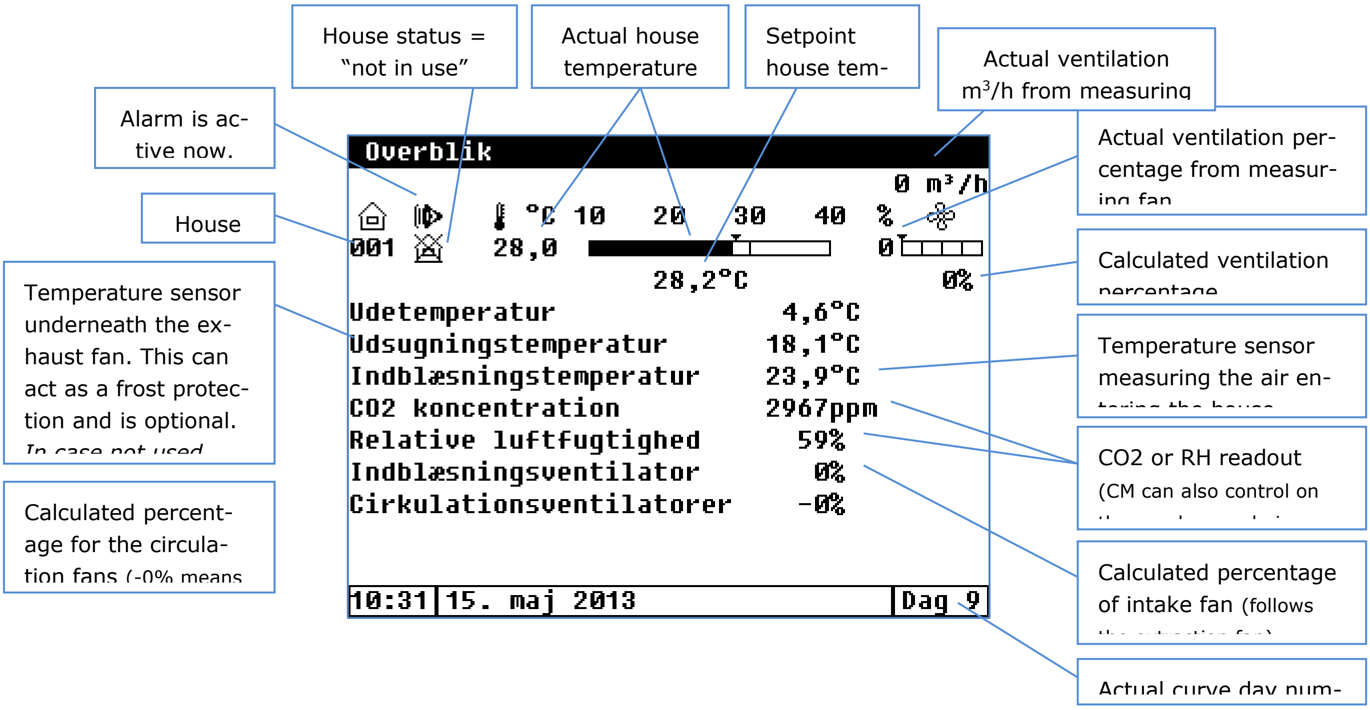
1. With the arrow up ▲(+) / down ▼ (-) can the boxed number changed. Then one can with the right arrow ► jump to the next number to change this in the same way: **050**
2. It is also possible to use the numeric keypad to key in the number immediately.

If eventually the number is changed to the correct value, this must be confirmed with the "***enter***" key. If one does NOT want to change the value, or to go back one menu, the "**C**" key should be used.

A useful feature is the number on any screen (except for the overview and main menu screen) in the upper left corner. This is the order of numbers, to get from the main menu, to the appropriate screen to go!

23.

24. OVERVIEW SCREEN CLIMA MANAGER



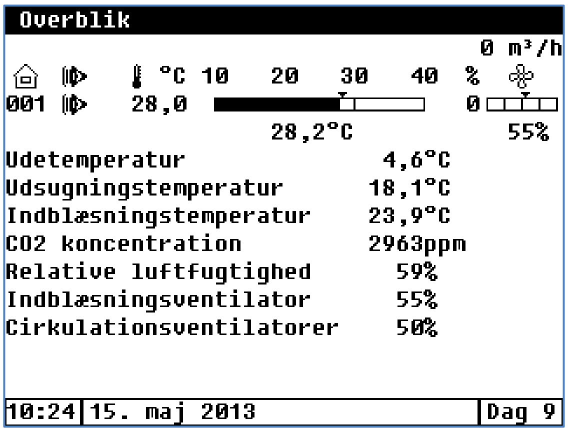
The overview screen can look different according to items which are in the installer setting activated or not. Items are only visible when installed!

25.EXPLANATION OF THE SCREENS

26.CLIMA MANAGER

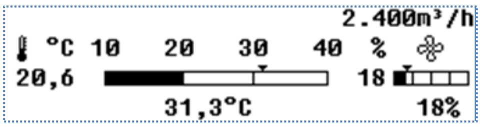
The large graphic display on the Clima Manager can show several screens of information about the status of the heat exchanger. **Since the information visible institutions determined by the installer settings, it may be that the scenes shown in the examples do not correspond with those in your own computer. Items that are not installed therefore are not shown.**

There are three speed dial keys F1, F2 and F3, and an alarm button. The most common screens or selections are thus easily accessible.
F1: Manual Controls
F2: House status
F3: Graphs button to quickly switch between data and a graph display in some scenes.
To select menu F1 or F2, the function buttons need to be hold for 1 second!



Overview screen:
If the Clima Manager is not touched for a few minutes, the display light will go out and jump back to the overview screen. Here one can also come from any screen by repeatedly pressing the [C] key.
The [C] key is always a screen jumped back.

As the name suggests, here are the latest things in one glance.
(Data in this screen cannot be changed!)



Below the two horizontal bars, the setpoints are displayed, while in front of them the actual measured value is displayed. Left is the house temperature and on the right is the ventilation. (extracted air)
In the upper right corner the actual air quantity is displayed in m³/h.

In the lower left the present time and date is displayed; on the right the present (curve) day number.

```
Hovedmenu

1 Manuel kontrol
2 Klima kontroller
3 -------
4 Timere
5 Info

6 Alarm

7 System
Adgangskode            0000

09:34|15. maj 2013        |Dag 9
```

Main menu:
From the overview screen by pressing the "**en-ter**" button you get to the main menu.

The final line [**Access code**] is intended only for the installer and is protected by a code. Here, once all the allocations for the entire installation will be done. In case there are some changes done in here by unauthorized people, this may result in wrong functioning of the Clima+ unit.

Main menu: 1 Manual control

```
1 Manuel kontrol

Udsugningsventilator       auto
Indblæsningsventilator     auto

Clima+ ventil              auto
Bypass Clima+              auto
Louvre box                 auto

Cirkulationsvent.          auto
Recirk. varmemodul         auto

Vaske timer 1              auto
Vaske timer 2              auto
09:37|15. maj 2013        |Dag 9
```

```
1 Manuel kontrol

Udsugningsventilator       man.  ☞  070%
Indblæsningsventilator     auto

Clima+ ventil              auto
Bypass Clima+              auto
Louvre box                 auto

Cirkulationsvent.          auto
Recirk. varmemodul         auto

Vaske timer 1              auto
Vaske timer 2              auto
09:41|15. maj 2013        |Dag 9
```

Main menu => [**1**]
- [1] **Manual control**

The manual control menu is also directly accessible by pressing the **[F1]** key. (Hold button F1 for 1 second) Here, all visible arrangements can be operated manually, if that would be necessary. Normally, all will be set to AUTO and the Clima Manager does its job.

Should a situation occur for a particular item and so should be set to manual, you can simply select the relevant scheme and change the field [**auto**] after pressing the "enter" button. Then the choice [**man.**] is selected and confirmed by "enter". At the time the option "MANUAL" is confirmed, there will also be the symbol of a hand to clearly indicate that a value can be entered manually. From that moment onward, the control will stay at this set value.

Even though the house status is set to "not in use", the manual control has priority over that.

In this example, the setting for the extraction fan manually is set at 70%.

If there are one or more manual controls active, this is demonstrated by a flashing red LED in the **[F1]** button. This serves to remind you that there is a manual operation is active.

Main menu: 2 Climate controls

```
2 Klima kontroller

1 Stald status             i brug
2 Udsugningsventilator
3 Indblæsningsventilator
4 Ventiler Clima+
5 Cirkulationsventilatorer
6 Varme
7 Diverse

8 Vækstkurver

9 Alarm
09:47|15. maj 2013        |Dag 9
```

```
21 Stald status

Stald status               i brug
Vækstkurve temperatur      +0,0°C   28,2°C
Staldtemperatur            27,6°C

Vækstkurver                 on
  Dag                       009        9
  Corr.                     +00

Vaske timer 1               off
Vaske timer 2               off

09:49|15. maj 2013        |Dag 9
```

If in a screen the text is underlined, such as "Growth curve temperature" in above example, this text can be selected as well. By pressing the enter button on this text

"7 ------------" Hyphens in a menu, indicate that the choice is not available. The installer has during the setup / assignments of the house

Main menu => [**21**]
- [2] Climate Controls
  [1] **House status**

F2

The House status menu is also directly accessible by pressing the F2 key.
Here, the most important items quickly can be checked and changed when needed.

House status
- "**in use**": This means that the CM runs in automatic mode. The Clima+ unit is used!
- "**not in use**": This means that the CM is not running, all automated controls are stopped. (Controls set on manual, however, will continue to work!)
- "**cleaning**": Before switching the CM to "not in use". This function can be activated to start an extra intensive cleaning process. This process can be programmed in advance at the time clocks.

Growth curve temperature
- If a curve is activated, here through an offset to the target for the house (far right value) can be changed.
- If no curve has been activated for the house temperature, immediately the target for the house is entered.

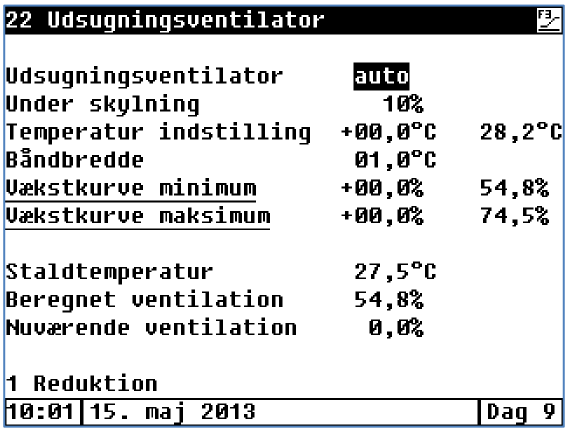
House temperature
- Measured house temperature. *(If several temperature sensors are assigned, the average temperature will be displayed! Also the temperature will be underlined, to being able to read each sensor individually)*

Growth Curves
- Here all curves immediately can be switched on or off. (*If off, the computer will work with the last settings*)

Day
- Here the age of the animals should be set. Far right is the day number where the curve data is collected from. (+ or – correction)

Corr.
- It is possible to shift the curve day, if the desired conditions are in the house are not as expected. However, this correction by plus or minus offset, one can easily come back to the original curve by making this correction zero again..

Main menu: 2 Climate controls



Main menu => [**22**]
- [2] Climate Controls
  - [2] **Extraction fan**

This is the overview screen for the extraction fan, which is leading. The intake fan will follow the extraction fan. Here can be read out, but also set, how the heat exchanger should work. In this example on the left, the maximum value is set higher, to make it possible to ventilate extra in case needed. In case this is not desired, this can be altered at the maximum ventilation curve.
In subsequent scenes, the Clima Manager works more intelligent and can be applied first to increase ventilation and if the house temperature gets too warm, the ventilation will be decreased to an absolute minimum.

Extraction fan
- Like in the manual menu, also here the control for extraction fan can be swapped between auto and manual.

During rinse cycle
- Here the desired position of the extraction fan can be set during "rinsing". *(If it is set at 0%, the extraction fan will stop during the rinsing process and it is possible that by the negative pressure in the house, water (mist) will be drawn back into the house.)*

Temperature setting
- Here the target temperature for the extraction fan (main control) can be changed from the curve. (*To the right is the calculated value.*)

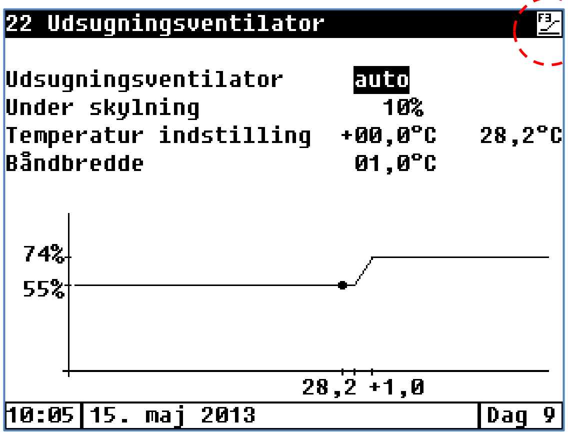
Bandwidth
- If the ventilation can increase, here can be filled in how many degrees the ACM should go from minimum to maximum ventilation.

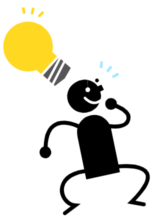
Growth curve minimum
- This value is extracted from the curve and can be adjusted through an offset here. (*To the right is the calculated value*)

Growth curve maximum
- This value is extracted from the curve and can be adjusted through an offset here. (To the right is the calculated value)

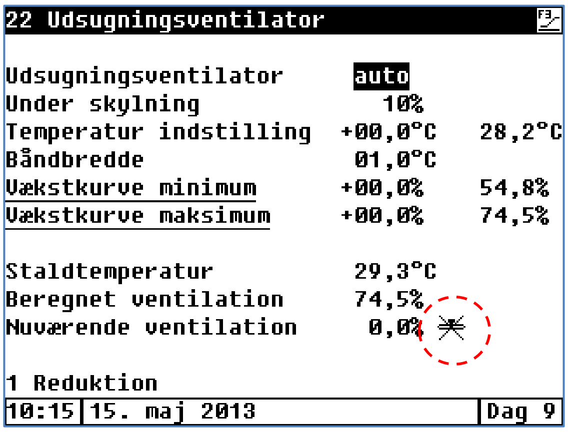
House temperature
- Measured house temperature. (If several temperature sensors are assigned, this value is the average temperature!)

Calculated ventilation
- Based on the measured temperature and temperature setting, the actual ventilation value is determined.





Wherever the F3 symbol apears in the upper right corner on the screen, the F3 key can toggle between display in tabular or graphical format. At curve settings, this can provide a much better overview.

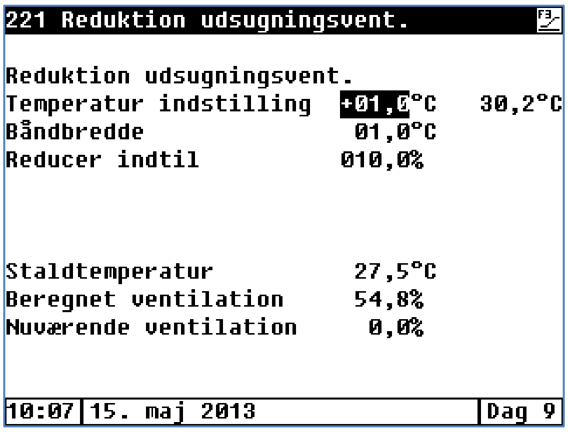


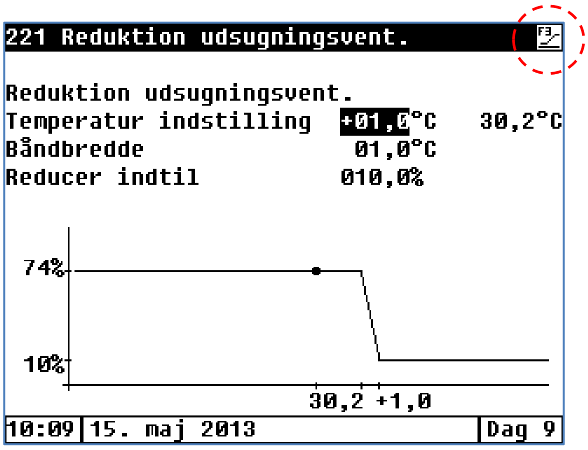
Current ventilation

- Reading of the measuring fan.
  (If the alarm for this is off (menu 294), this is illustrated with a symbol of a measuring fan with a cross through it, right along the measured value.) ***The computer operates on the value calcu-lated without measuring fan.***

1 Reduction

- *This menu is only visible if it is activated in the installation menu.*





Main menu => [**221**]

- [2] Climate Controls
  - [2] Extraction fan
    - [1] **Reduction extr. fan**

Temperature setting

- Here you set after how many degrees, the Clima Manager has to decrease the ventilation again.
  Left is the offset (the horizontal part)
  Right is the calculated temperature.

Bandwidth

- This is how fast (in how many degrees) the ventilation is reduced to the absolute minimum value entered below.
  Reduce until
  Theoretically, the Clima+ unit might decrease to 0% ventilation, but this could cause drafts created by the opening of the Clima+ unit. Therefore it might be better to leave the Clima+ unit running for example on 10% continue, to prevent air coming back into the house via the extraction trajectory.

House temperature

- Measured house temperature. *(If several temperature sensors are assigned, this value is the average temperature!)*

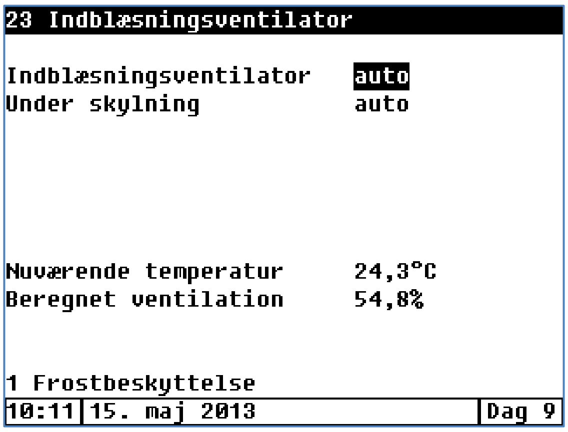
Calculated ventilation

- Based on the measured temperature and temperature setting, the actual ventilation value is determined.

Current ventilation

- Reading of the measuring fan.
  (If the alarm for this is off, this is illustrated with a symbol of a measuring fan with a cross through it, right along the measured value.) *The computer operates on the value calculated without measuring fan.*

Main menu: 2 Climate controls



Main menu => [**23**]

- [2] Climate Controls
  - [3] **Intake fan**

Usually there is no separate air measuring unit provided for the air intake fan. The control of the inlet fan follows the extraction fan, which is leading.

<u>Intake fan</u>

- Like in the manual menu [F1], also here the control for the intake fan can be changed from AUTO to HAND and back.

<u>During rinse cycle</u>

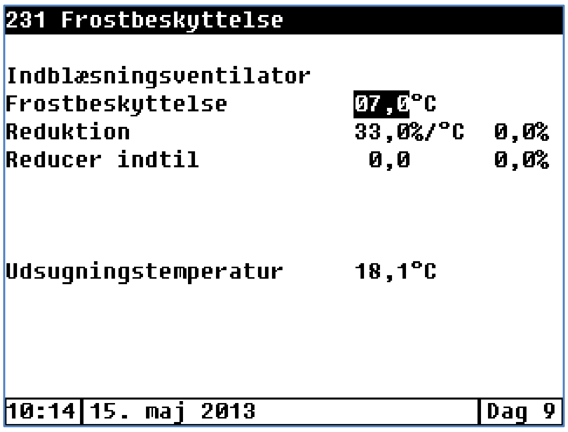
- **“Auto”** The intake fan remains in the same position as that it was just before rinsing. **“man.”** The position of the intake fan during "rinse" can then be fixed. *(If set to 0%, the intake fan stops during the rinse process)*

<u>Current temperature</u>

- This is the measured air intake temperature, fresh air through the Clima+ unit which goes into the house.

<u>Calculated ventilation</u>

- Based on the measured temperature and temperature setting, the actual ventilation value is determined. *(This follows the extraction control.)*



Main menu => [**231**]

- [2] Climate Controls
  - [3] Intake fan
    - [1] **Frost guard**

<u>Frost guard</u>

- In case a temperature sensor *(optional)* is installed below the extraction fan, this can work as a frost protection and prevent the heat exchanger from freezing completely. When that happens the extraction trajectory will be blocked with ice and no air can go out any more. In this example the speed of the intake fan will be reduced when the temperature below the extraction fan reaches 7,0 °C or less.

<u>Reduction</u>

- The fan will be reduced with 33% per degrees of Celsius; which is equal to a bandwidth of 3,0 degrees. By taking less cold air through the Clima+ unit then warm air leaves through the unit, the heat exchanger will not freeze.

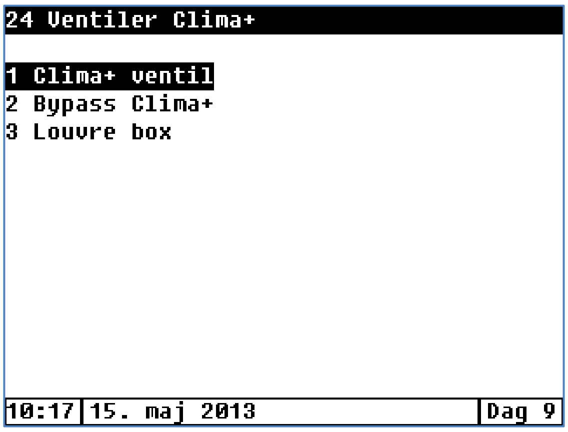
<u>Reduce until</u>

- Until what value the intake fan is allowed to reduce.

<u>Extraction temperature</u>

- This is the measured temperature below the extraction fan.

Main menu: 2 Climate controls



Main menu => [**24**]
- [2] Climate Controls
  [4] **Valves Clima+**

In case there are valves installed inside the Clima^{+} unit, they will be assigned in the installer settings and here visible.

[1] Clima+ valve

=> The *Clima+ valve* is a valve that can close the fresh incoming air off through the heat exchanger. This will be the case if there is also a heater inside the Clima^{+} unit.

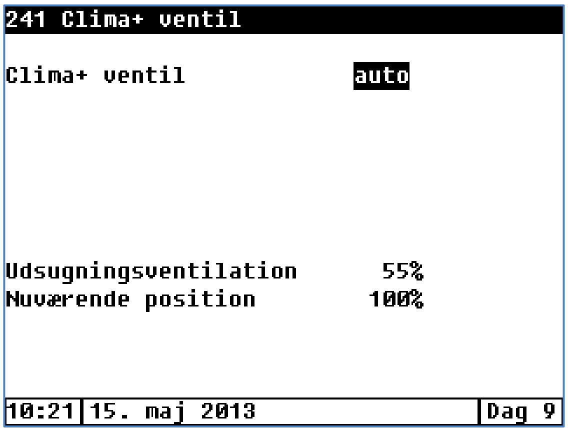
[2] Bypass Clima+

=> The *Bypass Clima+* valve, can be used in warm days, to bypass the incoming fresh air from the heat exchanger, to prevent it from extra heating, before entering the house.

[3] Louvrebox

=> The *Louvrebox valve* is a valve after the intake fan and will push the fresh intake air into the ridge of the house. This valve is part of the ***louvrebox***.

Main menu: 2 Climate controls



Main menu => [**241**]

- [2] Climate Controls
  - [4] Valves Clima+
    - [1] **Clima+ valve**

Clima+ valve

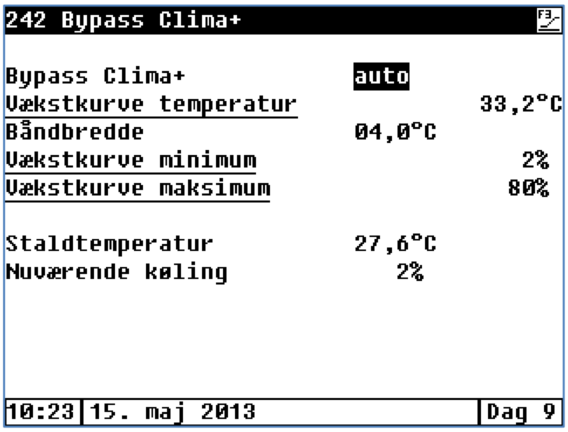
- Also here the Clima+ valve can be set to HAND or AUTO.

Extraction ventilation

- This is the calculated value for the extraction ventilation.

Current position

- Read out of the position of the Clima+ valve.



Main menu => [**242**]

- [2] Climate Controls
  - [4] Valves Clima+
    - [2] **Bypass Clima+**

Bypass Clima+

- Also here the bypass Clima+ valve can be set to HAND or AUTO.

Growth curve temperature

- Start value according to its own curve.

Bandwidth

- Control Band in how many degrees the valve position goes from minimum to maximum position.

Growth curve minimum

- Minimum opening according the curve.

Growth curve maximum

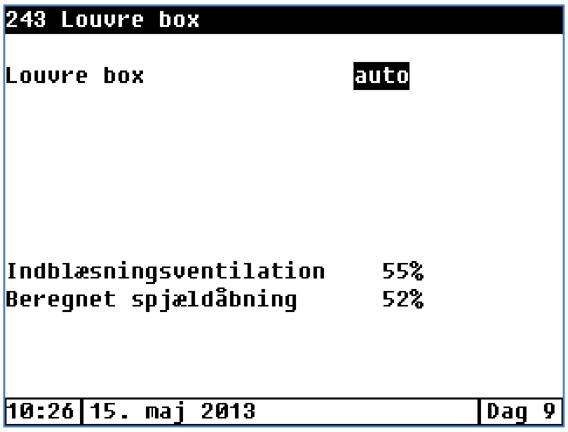
- Maximum opening according the curve.

House temperature

- Measured house temperature. (*If several temperature sensors are assigned, this value is the average temperature!)*

Current cooling

- Percentage how far the bypass Clima+ valve is open, based on cooling.



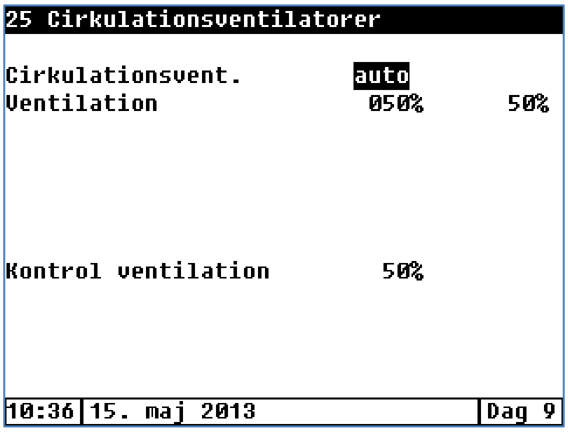
Main menu => [**243**]
- [2] Climate Controls
  - [4] Valves Clima+
    - [3] **Louvre box**

Louvre box
- Also here the Louvre box valve can be set to HAND or AUTO.

Intake ventilation
- Calculated value of the intake fan.

Calculated flap opening
- Actual position of the intake flap of the louvre box.

Main menu: 2 Climate controls



Main menu => [**25**]

- [2] Climate Controls

  [5] **Circulation fans**

Circulation fans

- Like in the manual menu, also here the control for circulation fans can be swapped between auto and manual.

Ventilation

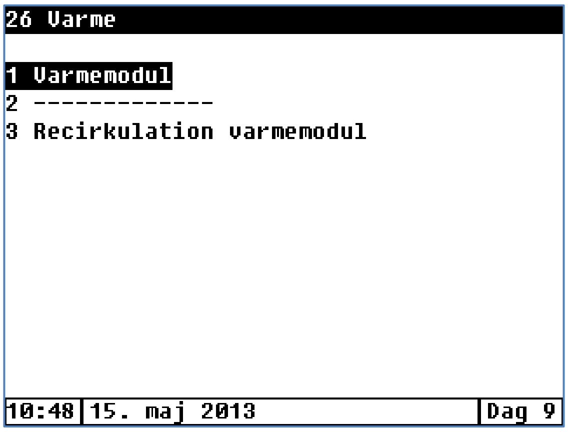
- On the left is the set value or the value calculated from its own curve.

  On the right is the calculated value.

Control ventilation

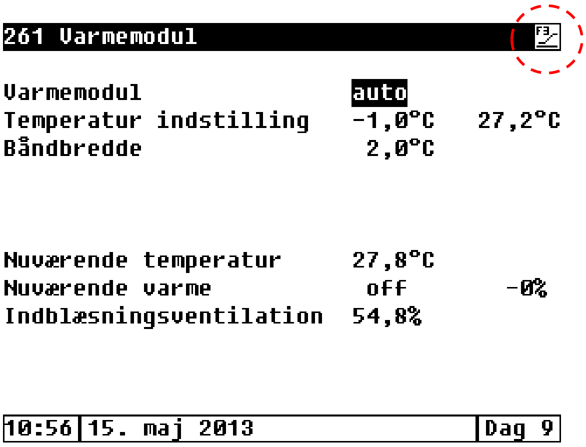
- Actual control of the circulation fans.

Main menu: 2 Climate controls



Main Menu => [**26**]
- [2] Climate Controls
  [6] **Heating**

[1] Heater block
=> Settings for the heater.
[2] Bypass heater
=> The bypass heater is a valve that can bridge the heater when not in use.
[3] Recirculation heater
=> The recirculation heater valve is a valve that recirculates house air back to the intake fan. This control can be used with an extra air measuring unit. In this way the house air can be reheated.



Main menu => [**261**]
- [2] Climate Controls
  [6] Heating
  [1] **Heater block**

Heater block
- If needed, here the heater can be switched off only.

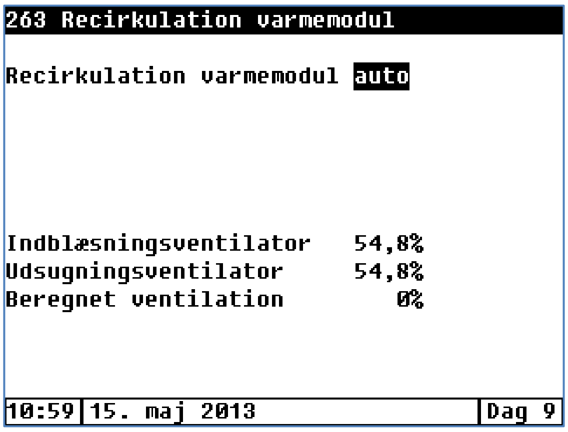
Temperature setting
- The heating works in its own curve, which is linked to the house curve. If needed, an offset can be entered here.
  On the right, the calculated value is displayed.

Bandwidth
- Control range for the heating. (Watermixingvalve)

Current temperature
- Current house temperature.

Current heating
- Status of the heater. (On / off and controlled heating percentage)

Intake ventilation
- Percentage of air through the intake fan. (If the heating is on, this will be a pre-set value.)



Main menu => [**263**]
- [2] Climate Controls
  - [6] Heating
    - [3] **Recirculation heater**

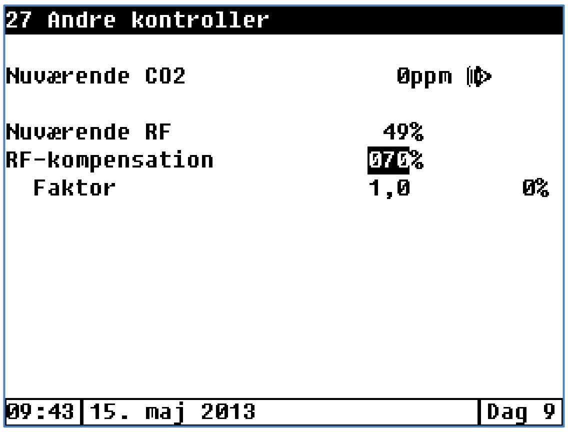
Recirculation heater
- The recirculation valve can be set to HAND.

Intake fan
- Percentage of the air through the intake fan.

Extraction fan
- Percentage of air through the extraction fan.

Calculated ventilation
- Calculated control of the recirculation valve.

Main menu: 2 Climate controls



Main menu => [**27**]
- [2] Climate Controls
  - [7] **Miscellaneous controls**

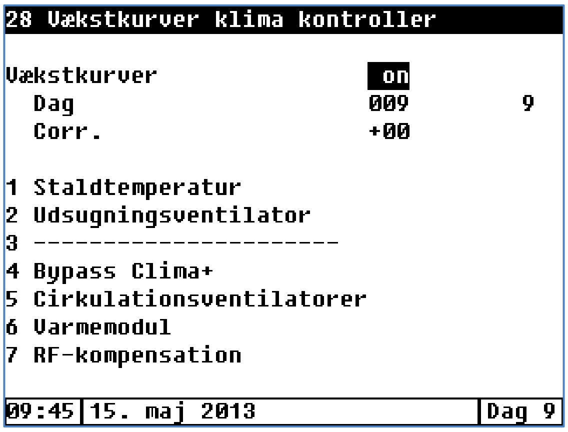
Current RH
- Measurement of the actual Relative Humidity (RH)

RH-compensation
- From this percentage onwards, the ventilation will be increased.

Factor
- RH compensation factor. In the installation settings it can be set to be absolute or relative.

It's also possible only to measure RH, without any compensations to be activated.

Main menu: 2 Climate controls

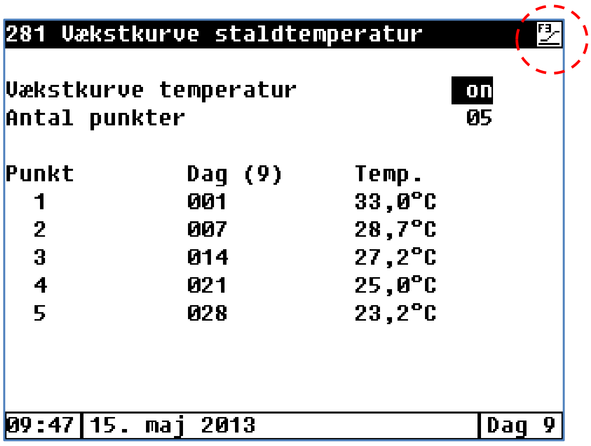


Main menu => [**28**]
- [2] Climate Controls
  [8] **Growth curves clim. controls**

As in screen [21] House status (= **F2**), also here all the curves can be switched ON or OFF. Also the current day number can be changed from here.

If the growth curves are switched off, the CM works with default settings.

At the sub menus 1 through 7, each curve can be set individually.



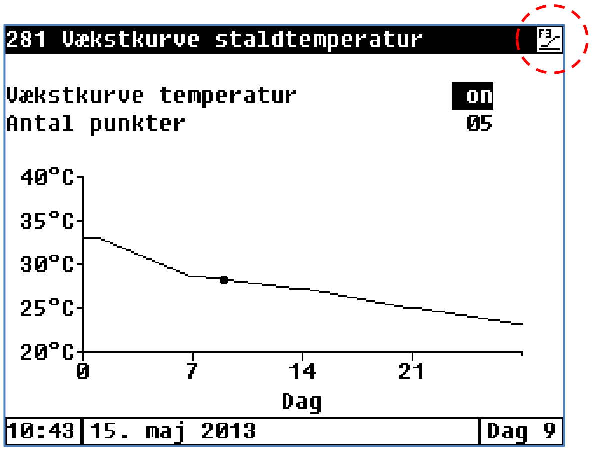
Main menu => [**281**]
- [2] Climate Controls
  [8] Growth curves climate controls.
  [1] **Growth curve house temp.**

This curve is the main curve of the Clima Manager. This must be copied from the existing house climate computer. This allows the Clima Manager to work together with the house climate computer.

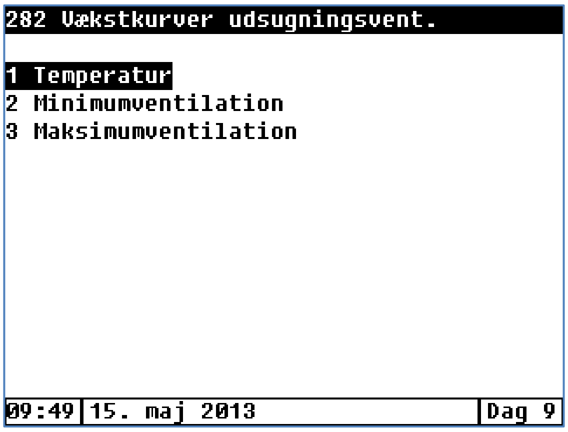
<u>Growth curve temperature</u>
- Here each curve can be individually switched ON or OFF.

<u>Number of points</u>
- Here the required number of break points can be entered. (*Max. 15 break points*)

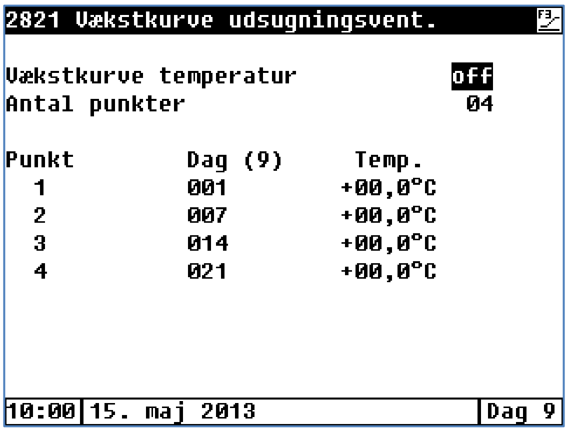
Subsequently, behind each breakpoint number, the curve day and corresponding house temperature can be entered.



By pressing **[F3]**, the entered curve can be displayed in a graph. By the means of this it’s easier to spot any typing errors.



Main menu => [**282**]
- [2] Climate Controls
  - [8] Growth curves climate controls
    - [2] **Growth curves extract. fan**

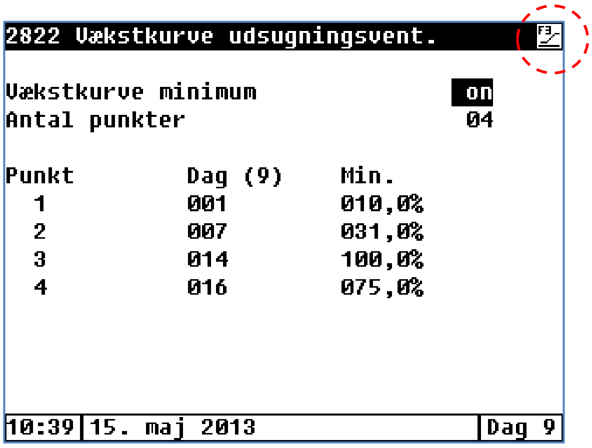


Main menu => [**2821**]
- [2] Climate Controls
  - [8] Growth curves climate controls
    - [2] Growth curves extraction fan
      - [1] **Temperature**

<u>Growth curve temperature</u>
- Here each curve can be individually switched ON or OFF.

<u>Number of points</u>
- Here the required number of break points can be entered. (*Max. 15 break points*)

Subsequently, behind each breakpoint number, the curve day and corresponding offsets relative to the house temperature can be entered.



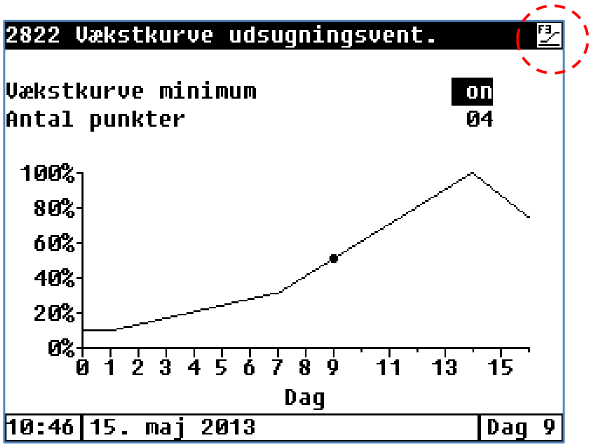
Main menu => [**2822**]
- [2] Climate Controls
  - [8] Growth curves climate controls
    - [2] Growth curves extraction fan
      - [2] **Minimum ventilation**

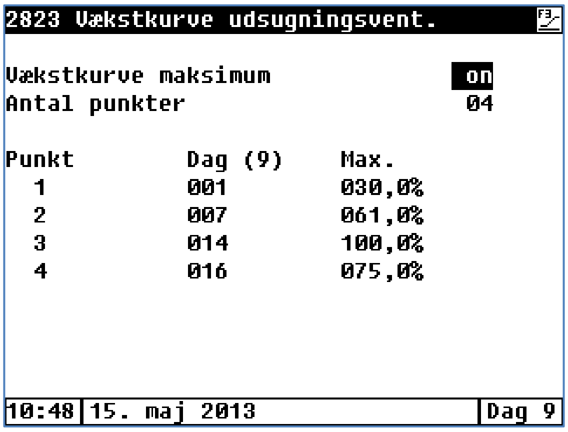
<u>Growth curve minimum</u>
- Here each curve can be individually switched ON or OFF.

<u>Number of points</u>
- Here the required number of break points can be entered.

Subsequently, behind each breakpoint number, the curve day and corresponding minimum ventilation settings can be entered.

By pressing **[F3]**, the entered curve can be displayed in a graph. *By the means of this it's easier to spot any typing errors.*





Main menu => [**2823**]
- [2] Climate Controls
  - [8] Growth curves climate controls
    - [2] Growth curves extraction fan
      - [2] **Maximum ventilation**

<u>Growth curve maximum</u>
- Here each curve can be individually switched ON or OFF. In case the Clima Manager only needs to work according a minimum curve, then the setting "**min**" should be selected and the maximum curve will follow the minimum curve settings.

<u>Number of points</u>
- Here the required number of break points can be entered. (*Max. 15 break points*)

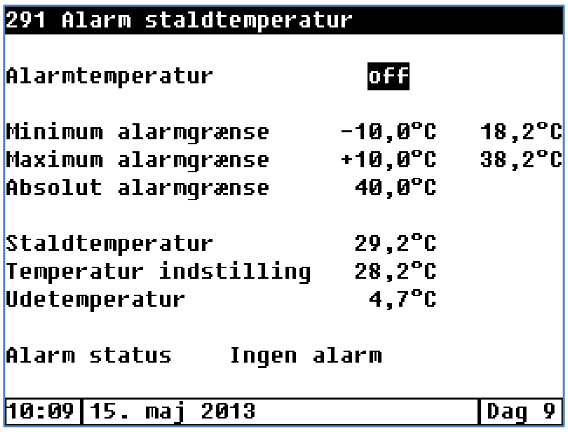
Subsequently, behind each breakpoint number, the curve day and corresponding maximum ventilation settings can be entered.

In a similar way, the other curves can also

Main menu: 2 Climate controls

Main menu => [**29**]
- [2] Climate Controls
  [9] **Alarm climate controls**

In this menu system alarm conditions can be set for each control separately.



Main menu => [**291**]
- [2] Climate Controls
  [9] Alarm climate controls
  [1] **Alarm house temperature**

Alarm temperature
- Here the alarm for the house temperature can be switched on or off. *(In case the house curve is not set, this should be switched off to prevent any false alarm.)*

Minimum alarm limit
- Lowest alarm limit is -20°C below the set point of the house temperature.

Maximum alarm limit
- Highest alarm limit is +20°C above the calculated set point for the house temperature.

Absolute alarm limit
- Absolute maximum alarm limit.

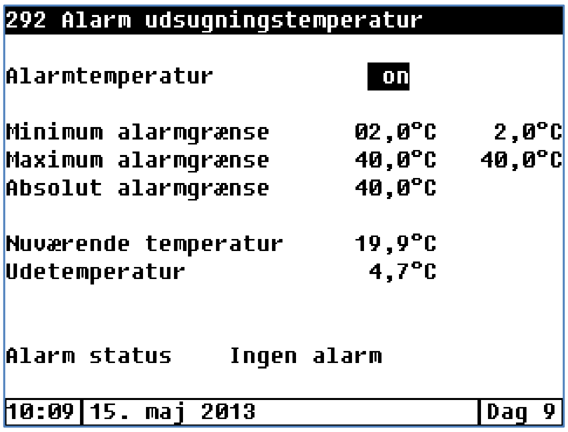
House temperature
- (Average) house set point..

Temperature setting
- Set point house temperature.

Outside temperature
- Measured outside temperature.

Alarm status
- Actual status of this alarm control. *In this example there is **no** alarm active for this control!*

When the outside temperature gets higher than the set point house, the maximum alarm limit will also move up.



Main menu => [**292**]
- [2] Climate Controls
  - [9] Alarm climate controls
    - [2] **Alarm extract. temperature**

<u>Alarm temperature</u>
- Here the alarm for the temperature below the extraction fan can be switched on or off.

<u>Minimum alarm limit</u>
- Absolute minimum value for the temperature to reach below the extraction fan.

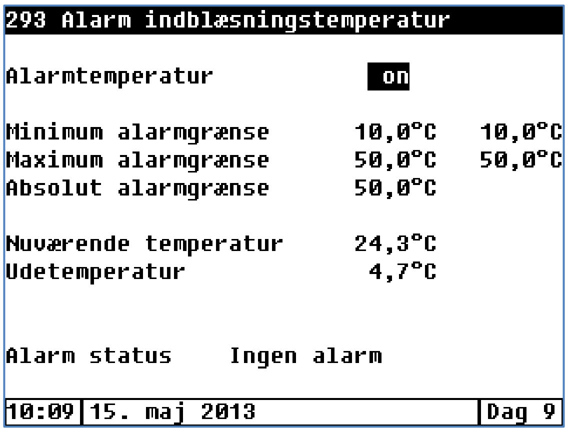
<u>Maximum alarm limit</u>
- Absolute maximum value for the temperature to reach below the extraction fan.

<u>Absolute alarm limit</u>
- Absolute maximum alarm limit.

<u>Current temperature</u>
- Actual measurement of the temperature sensor below the extraction fan.

<u>Outside temperature</u>
- Measured outside temperature.

<u>Alarm status</u>
- Actual status of this alarm control.



Main menu => [**293**]
- [2] Climate Controls
  - [9] Alarm climate controls
    - [3] **Alarm intake temperature**

<u>Alarm temperature</u>
- Here the alarm for the intake temperature sensor can be switched on or off.

<u>Minimum alarm limit</u>
- Absolute minimum value for the intake temperature.

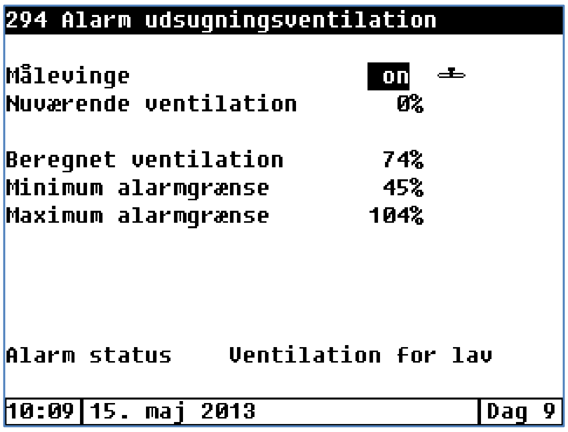
<u>Maximum alarm limit</u>
- Absolute maximum value for the intake temperature.

<u>Absolute alarm limit</u>
- Absolute maximum alarm limit.

<u>Current temperature</u>
- Actual measurement of the intake temperature sensor.

<u>Outside temperature</u>
- Measured outside temperature.

<u>Alarm status</u>
- Actual status of this alarm control.



Main menu => [**294**]

- [2] Climate Controls
  - [9] Alarm climate controls
    - [4] **Alarm extract. ventilation**

<u>Measuring fan</u>

- Here the alarm for the measuring fan can be switched on or off. *(This can be done when the measuring fan becomes faulty.)*

<u>Current ventilation</u>

- The actual measurement of the measuring fan.

<u>Calculated ventilation</u>

- The calculated ventilation at this moment.

<u>Minimum alarm limit</u>

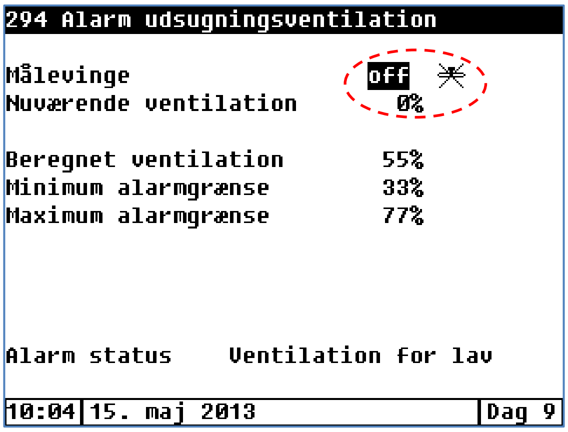
- When the actual measurement becomes below this limit, there will be alarm.

<u>Maximum alarm limit</u>

- When the actual measurement becomes above this limit, there will be alarm.

<u>Alarm status</u>

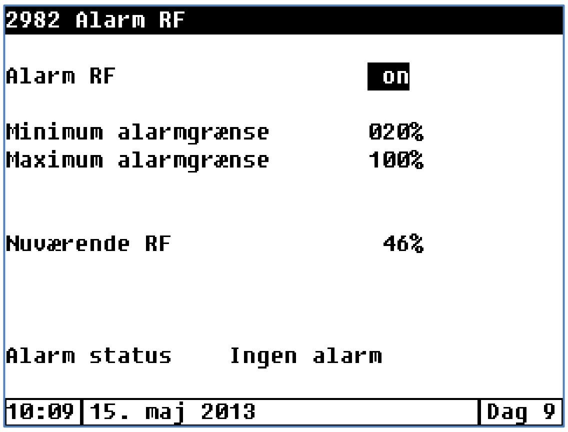
- Actual status of this alarm control.
  (In this example this control gives an alarm; the calculated value is 18%, while the measured value equals 0%!)



In case the alarm for the measuring fan is switched off, a cross will be displayed through the fan symbol, to indicate that the alarm is switched off and the control will be done **with-out** measuring fan

Main menu => [**298**]
- [2] Climate Controls
  - [9] Alarm climate controls
    - [8] **Alarm miscel. controls**

In case CO2 or RH is measured, here the alarm settings can be altered.



Main menu => [**2982**]
- [2] Climate Controls
  - [9] Alarm climate controls
    - [8] Alarm miscel. controls
      - [2] **Alarm RH**

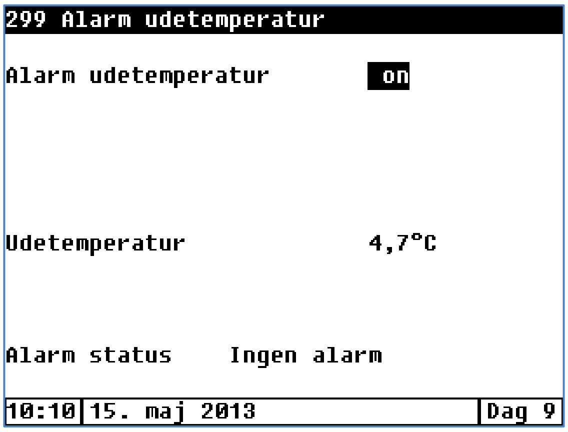
Alarm RH
- Here the alarm for the house RH can be switched on or off.

Minimum alarm limit
- At this value there will be an alarm.

Maximum alarm limit
- At this value there will be an alarm.

Current RH
- Actual RH measurement.

Alarm status
- Actual status of this alarm control.



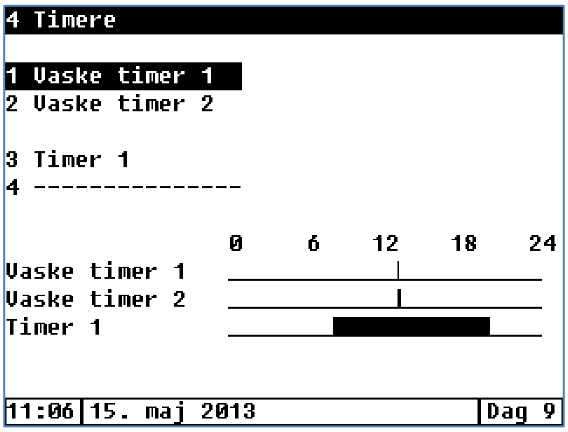
Main menu => [**299**]
- [2] Climate Controls
  - [9] Alarm climate controls
    - [9] **Alarm outside temperature**

Alarm outside temperature
- Here the alarm for the outside temperature alarm can be switched on or off.

Outside temperature
- Measured outside temperature.

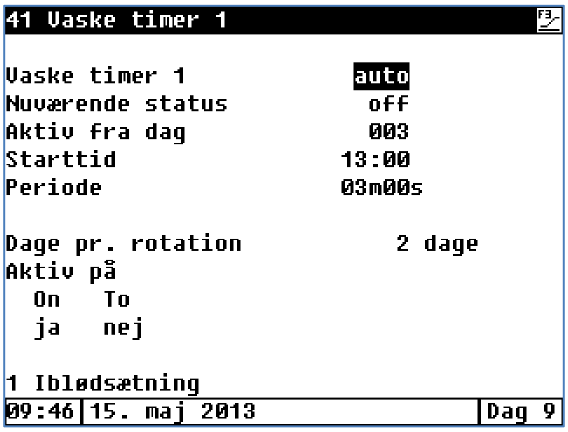
Alarm status
- Actual status of this alarm control.

Main menu: 4 Timers



The rinse timers should be used if the Clima Unit has a rinsing system. The moment a rinse timer is running, the extraction fan will start to run on a preset speed throughout the rinsing period. This setting can be done at ***[22] Extraction fan.***

The inlet fan percentage is then calculated according to value, unless it has its own air measuring unit.



Main menu => [**41**]

- [4] Timers

  [1] **Rinse timer 1**

<u>Rinse timer 1</u>

- Like in the manual menu, also here the status for the rinse valve can be swapped between auto and manual.

<u>Current status</u>

- Readout if the timer is active.

<u>Active from day</u>

- The timer will start to work from this day onwards. This choice can be enabled or disabled from the installer menu.

<u>Start time</u>

- Start time when this rinse valve should start.

<u>Period time</u>

- Duration of rinse timer 1 when started.

<u>Days in cycle</u>

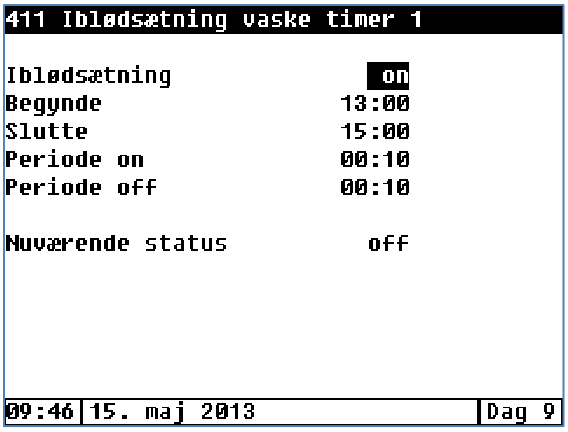
- Number of days to pre-program the “skip-a-day” program

<u>Active on</u>

- Below each shown day can be set if the rinse timer should be active that day.

It’s also possible to work with a “skip-a-day” program. This needs to be activated in the installer settings.

The same applies for rinse timer 2, only the start time needs to be set exactly to the start time + duration of rinse timer 1



Main menu => [**411**]

- [4] Timers

  [1] Rinse timer 1

  [1] **Soaking rinse timer 1**

<u>Soaking</u>

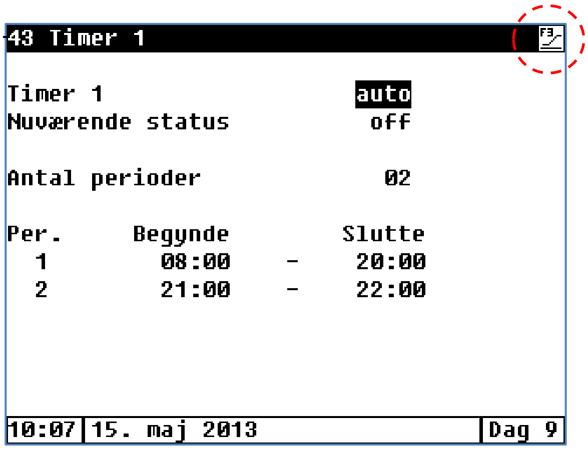
- Possibility to activate the soaking. Here this can be switched on or off.

<u>Begin / End</u>

- Beginning and end time of the cleaning process.

<u>Cycle time on / off</u>

- Rinse time and pause time during the cleaning process.



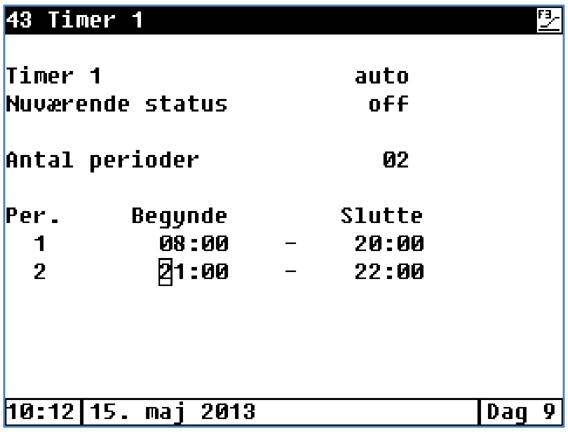
Main menu => [**43**]
- [4] Timers
  [3] **Timer 1**

Timer 1
- Here the timer can be set to HAND or AUTO.
  *(This is not possible in the manual control menu **[F1]**)*

Current status
- Readout if the timer is active.

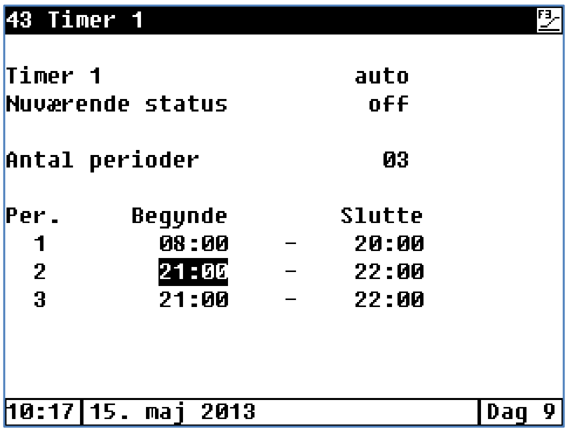
Number of periods
- Here you can indicate how many starting times / periods need to be entered.

By pressing the **[F3]** button, the entered time periods can be displayed in a graph.

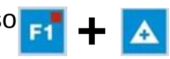


In case a new timer period needs to been entered in between two periods, this can be done easily without first manually moving the times.

- Go to the line where the new time period needs to be inserted and press the `enter` button.



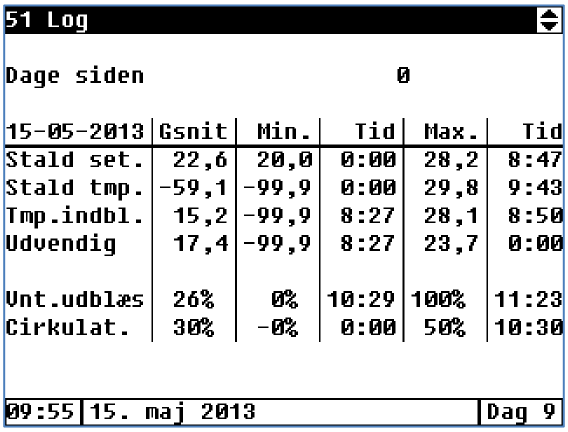
- When the box is open as in this example, press (and hold) the **[F1]** button. Then also press the **+** button *(= arrow up)* at the same moment.



- After doing that, an extra line will be inserted and can be set with the correct times.
- To remove a line works the same, except by using the **[F1]** and the **–** button.

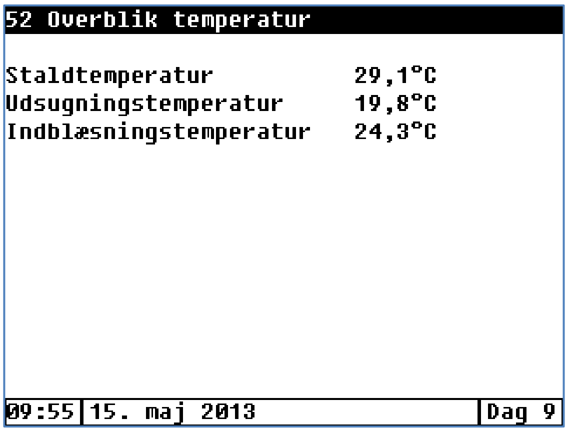
Main menu: 5 Info

This menu contains all the histories. The stored data from the last period can be examined here.



Main menu => [**51**]
- [5] Info
  - [1] **Log**

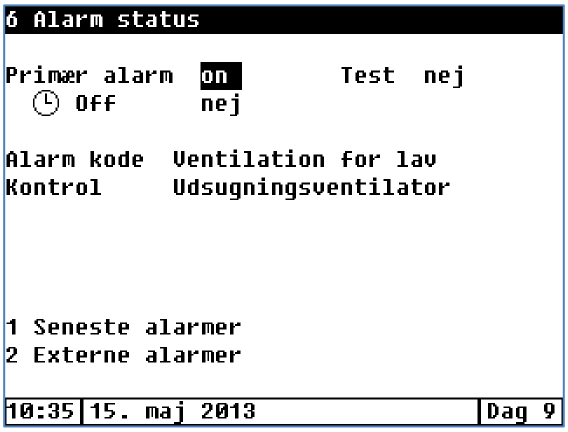
Here the status of the Clima+ Unit can be viewed back for the past 60 days.



Main menu => [**52**]
- [5] Info
  - [2] **Overview growth curves**

Here an overview of the measured temperatures can be seen.

Main menu: 6 Alarm



This alarm menu can also directly been approached through the red alarm button.

Main Alarm
- The complete alarm of the Clima Manager can here be switched ON or OFF.

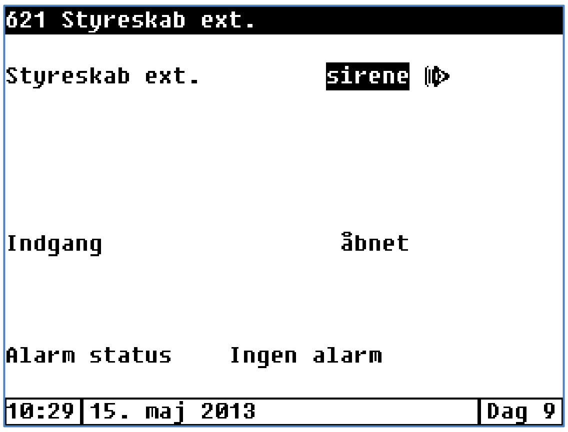
Test
- The alarm can easily being tested by choosing “yes”. During 10 seconds the alarm contact will be switched and should give an alarm to the alarm system.

- If there is an actual alarm, this can be temporarily switched off. After 30 minutes the alarm will be activated again if still not solved.

Alarm Code
- When an alarm occurs, here it will tell which alarm has been occurred.

Control
- When an alarm occurs, here it will tell which control has the alarm.

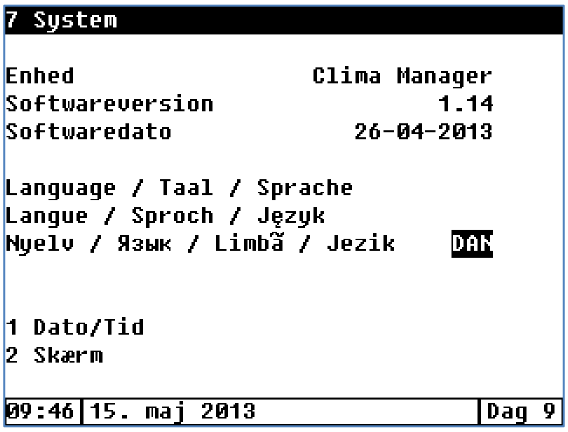
[61] Latest alarms
- In this sub-menu the last five occurred alarms will be stored.
  - ⇨ In case the time at ***Alarm 0*** is equal the actual time, the alarm is still active.
  - ⇨ In case the time at ***Alarm 0*** is **not** equal the time, then this is the time the last alarm (= ***Alarm 1***) has been solved.



[621] External alarms
- In this sub-menu settings can be made for external alarms, like in this example the electrical switchbox.
- In total 4 external alarms can be activated. *(If there are enough digital inputs available in the switchbox)*
- The name of every external alarm is free to change.

Control cabinet
- Here it can be selected how an alarm should be given:
  LOUD: Alarm message in display and alarm contact switched
  SILENT: Alarm message only in display
  OFF: External alarm switched off.

Main menu: 7 System



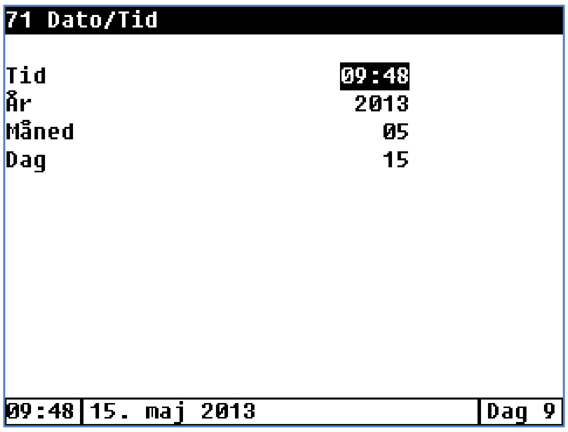
This menu contains general information about the Clima Manager.

Software version
- The version of this computer program.

Software date
- Release date of this computer program version.

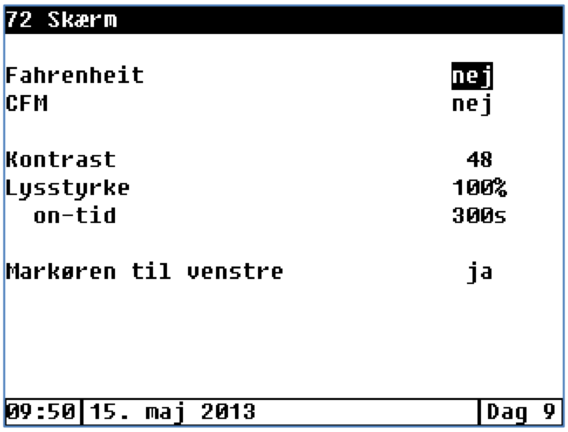
Language
- Here the language of the Clima Manager can be changed. *(Dutch, German, French, Danish, Polish, Hungarian, Russian, Romanian, Slovakian and English)*

The language can be changed in any given menu, with the following key combination: [▶] + F1



Main menu => [**71**]
- [7] System
  - [1] **Date / Time**

The current date and time can be adjusted here.



Main menu => [**72**]
- [7] System
  - [2] **Display**

Fahrenheit
- Choice to select Fahrenheit or Celcius. *(NO = °C)*

CFM
- Choice to select CFM (Cubic Feet per Minute) or m^3/h. *(NO = m^3/h)*

Contrast
- Setting for the readability of the display.

brightness
- Setting for the brightness of the display.

On- time
- If after this set time, no buttons are pressed, the display view will switch to the overview screen.

Cursor left
- This choice will determine where the cursor is normally. (Left or right)