DLG Test Report 6224

Big Dutchman International GmbH

MagixX-Pig+ three-stage exhaust air treatment system for pig housing

DLG SIGNUM TEST
04/15 passed

Test Center
Technology and Farm Inputs

www.DLG-Test.de

Overview

The SignumTest is the DLG's comprehensive usability test according to independent and recognised evaluation criteria for agricultural engineering products. The DLG SignumTest evaluates the essential product characteristics in a neutral manner – from efficiency and animal-welfare aspects to durability, workplace safety and functional reliability. Test rigs and a variety of operating conditions are used to test and evaluate both these aspects and the test object's successful operation in a field trial at a real-life farm. The exact testing conditions and methods, as well as the evaluation of the test results, are defined by the relevant independent testing boards in corresponding testing frameworks and constantly adapted to the recognised state of the art, as well as to scientific findings and agricultural requirements. The tests are performed according to methods that permit objective assessment based on reproducible values. A successful test concludes with the publication of a test report and the awarding of a test mark.

This DLG SignumTest tested the exhaust air treatment system from the company Big Dutchman GmbH with respect to its suitability for reducing dust, ammonia and odour emissions in the flow of exhaust air from litterless pig houses. The basis for the test is a ventilation system design according to DIN 18910 that conforms to the described process parameters for ammonia and dust separation of at least 70 % in each case. A value of 300 OU/m³ must not be exceeded in the scrubber's emissions, and there must additionally be no perceptible smell of untreated gas in the clean gas.

Assessment – Brief Summary

The MagixX-Pig+ exhaust gas treatment system from the company Big Dutchman is a two-stage chemical exhaust air scrubber with an additional biological filter stage for separating out dust, ammonia and odours from litterless pig housing with overhead ventilation. After entering the first scrubbing stage, which is operated at pH < 4, the exhaust air enters the second stage, which is also at pH < 4. Both stages are continuously irrigated with scrubbing water, and the receiving side of the first filter stage is also periodically presprinkled with scrubbing water. In the third stage, the exhaust air is forced through a root wood packing and thereby cleared of odorous substances. This type of system is based on a system certified according to the Cloppenburg guidelines [Cloppenburger Leitfaden]. The essential differences can be found in Table 1. In the test, the exhaust air purification system achieved an average ammonia separation of 84 %. In summer, the dust separation reached a value of up to 94 %. The results are summarised in Table 2. Further measuring results are presented from page 9 onwards.

Table 1:
Differences between the currently tested system and the system tested according to the Cloppenburg guidelines

	MagixX-Pig	**MagixX-Pig+**
Certified according to	Cloppenburg guidelines	DLG Testing Framework
Packing type	Paper filter and FKP 158	PP150
Continuous desludging	Manually after 3 months	At 130 mS or manually after 3 months
Fan controller	Multistep	Synchronous
1st filter stage	Physical purification (pH-neutral)	Chemical purification (pH < 4)

Table 2:
Overview of results

Test criterion	Result	Evaluation*
Results of emissions measurements		
Total dust (gravimetric)		
– Winter (2 measurements): mean separation efficiency [%]	87	+
– Summer (2 measurements): mean separation efficiency [%]	94	+ +
Fine dust (gravimetric)		
– Winter (2 measurements): mean separation efficiency PM_{10} [%]	90.3	+ +
– Winter (2 measurements): mean separation efficiency $PM_{2.5}$ [%]	97.4**	+ +
– Summer (2 measurements): mean separation efficiency PM_{10} [%]	88.5	+
– Summer (2 measurements): mean separation efficiency $PM_{2.5}$ [%]	93.5**	+ +
Ammonia (measured continuously, after the 2nd stage)		
– Winter: mean separation efficiency from half-hourly means [%]	86.8	+
– Summer: mean separation efficiency from half-hourly means [%]	81.0	+
N balancing		
– Summer: recovery rate of the separated nitrogen [%]	75	○
Odour		
– Summer and winter:	< 300 OU/m³ and no perceptible raw gas	N/E
Aerosol emissions after the 2nd filter stage (sulfate)		
– Winter: inorganic aerosol, mean [mg/m³]	0.41	N/E
Consumption measurements (mean values per day or per animal place and year)		
Fresh water consumption of exhaust air treatment system as a whole		
– Winter: fresh water consumption [m³/d] / [m³/(AP · a)]	2.80 / 0.67	N/E
– Summer: fresh water consumption [m³/d] / [m³/(AP · a)]	2.12 / 0.72	N/E
Fresh water consumption, biological filter only		
– Winter: fresh water consumption [m³/d] / [m³/(AP · a)]	0.51 / 0.12	N/E
– Summer: fresh water consumption [m³/d] / [m³/(AP · a)]	0.36 / 0.12	N/E
Desludging volume		
– Summer: desludging volume [m³/(AP · a)]	0.1125***	N/E
Acid consumption (with respect to 100 % sulfuric acid)		
– Winter: total acid consumption [kg/d] / [kg/(AP · a)]****	29.4 / 7.0	N/E
– Summer: total acid consumption [kg/d] / [kg/(AP · a)]	24.1 / 8.2	N/E
Electrical energy consumption		
Exhaust air purification (pumps)		
– Winter: energy consumption [kWh/d] / [kWh/(AP · a)]	70.8 / 16.9	N/E
– Summer: energy consumption [kWh/d] / [kWh/(AP · a)]	74.5 / 22.9	N/E
Fans		
– Winter: fans steplessly regulated [kWh/d] / [kWh/(AP · a)]	45.8 / 10.9	N/E
– Winter: fans unregulated [kWh/d] / [kWh/(AP · a)]	37.9 / 9.0	N/E
– Summer: fans steplessly regulated [kWh/d] / [kWh/(AP · a)]	47.1 / 15.9	N/E
– Summer: fans unregulated [kWh/d] / [kWh/(AP · a)]	14.6 / 4.9	N/E

* Evaluation range: + + / + / ○ / – / – – (○ = standard, N/E = not evaluated)

** From experience, the scrubbing process can cause the formation of droplets with sizes ranging from 2.5 to 10 µm, which can lead to a higher value for the particle fraction PM_{10} in the cascade impactor. The particle fraction $PM_{2.5}$ is less influenced by this effect. As a result, a greater separation efficiency is calculated for this particle fraction than for the PM_{10} fraction.

*** Calculated for an ammonia separation of 90 %

**** As there are no plausible measured values available for the winter measurement, the acid consumption for the period 4–24 April 2012 was calculated stoichiometrically from the recorded ammonia load at a separation efficiency of 84 %.

Test criterion	Result	Evaluation*
Operating behaviour		
Technical operational reliability	There were no significant faults in the system during the trial periods (apart from salt precipitation and dust deposition in the pressure chamber and fungal growth on the filter walls).	○
Biological operational reliability	Chemical scrubber with biological cleaning stage	○
Durability	No significant wear was identified during the trial periods.	+
Operation		
Operating instructions	The operating instructions are detailed and clear and provide explanations of the automatic controller and of maintenance that must be carried out.	+
Operation	The system is fully automatic under normal operating conditions; in the case of a maintenance contract, the manufacturer carries out a thorough inspection at least twice a year. The operator must inspect the system controller on a daily basis.	○
	The moistening of the biology in the 3rd stage is only operated intermittently because of the large amount of moisture introduced by the exhaust air. In the event of a failure of the first two cleaning stages, the biology must be irrigated continuously.	
Maintenance	The manufacturer always concludes a maintenance contract between itself and the operator. Remote monitoring of the system by the manufacturer is optionally available.	○
	After a maximum of three months all of the filter walls as well as the two water tanks must be cleaned .	
Cleaning the entire system	The packing is to be cleaned by the operator after three months at the latest.	○
	The two water tanks are to be completely emptied and cleaned after three months at the latest. The use of a pressure washer is recommended for cleaning.	
Changing the filter material	According to the manufacturer, it is not necessary to change the packing in the event of continuous operation. The biological stage must be replaced every 5–7 years.	N/E
Working time requirement		
– for daily inspections	Approx. 15 to 30 minutes per day (incl. changing acid & calibrating pH value)	○
– for weekly inspections	Approx. 60 minutes per week	○
– for cleaning	Approx. 1 day per cleaning, depending on size of system	○
Documentation		
Technical documentation	Requirements met	+
Electronic operating log	Requirements met	+
Safety		
Occupational safety	Confirmed by the German Centre for the Testing and Certification of Agricultural and Forestry Technology (DPLF) and the Social Insurance for Agriculture, Forestry and Horticulture (SVLFG)	N/E
Fire safety	A fire-protection concept is not required.	N/E
Environmental safety		
– Noise emissions	No increase can be detected in sound pressure level as a result of the exhaust air treatment system.	○
– Disposal	The desludged water from the first two water tanks must be stored in a separate sludge tank; at the same time, the specifications of the Fertiliser Ordinance (DüMV) must be adhered to for the storage of liquid manure. This may be applied to agricultural land, but the sludge water must not be mixed with liquid manure or water until just before application. Because of the risk of poisoning, the mixing must not be carried out in a stable occupied by animals. Escaping gases such as hydrogen sulfide and carbon dioxide can lead to symptoms of poisoning. Disposal of other system parts by accredited recycling facilities.	
Guarantee		
Manufacturer's guarantee	2 years	N/E

* Evaluation range: ++ / + / ○ / – / –– (○ = standard, N/E = not evaluated)

The Product

Manufacturer and Applicant

Big Dutchman International GmbH
PO Box 1163
49360 Vechta

Product:
MagixX-Pig+
exhaust air treatment system

Contact:
Telephone: +49 (0)4447 801-0
Fax: +49 (0)4447 801-237
www.bigdutchman.de

Description and Technical Data

The MagixX-Pig+ exhaust air treatment system from the company Big Dutchman is a three-stage combined system that is operated under pressure for the purification of exhaust air from litterless pig houses with overhead ventilation. The packing used is of the type PP150.

This exhaust air treatment system operates on the principle that the substances contained in the exhaust air will come into contact with the circulating acidic scrubbing water (pH < 4) and the microorganisms living in the biological stage. The exhaust air is extracted through all of the connected compartments and fed into the first filter stage via a collector duct. This filter consists of a plastic wall that is irrigated continuously at a rate of 1.04 $m^3/(m^2h)$. In addition, the filter is presprinkled using lines of jets mounted on the untreated-gas side in order to prevent dust from caking on. The high specific surface area of the filter material serves to enlarge the contact area between the exhaust air and the water in order to improve the absorption of dust and ammonia. The pH value of < 4 causes an increase in the ammonia absorption capacity of the scrubbing water. The use of sulfuric acid causes the ammonia absorbed by the scrubbing water to react to form ammonium sulfate.

The second stage has a construction identical to that of the first stage and is used to scrub out ammonia and dust. Once again, the pH of the scrubbing water is regulated at a value of < 4. In contrast to the first stage, presprinkling is no longer performed here. The irrigation density is 0.67 $m^3/(m^2h)$.

The water tanks of the two scrubbing stages are physically separate from one another and are kept at a constant fill level with fresh water by a level monitoring system.

To prevent accumulation of salts such as ammonium sulfate, it is necessary to desludge the scrubbing water. At a conductivity of 130 mS/cm or after three months at the latest, both water tanks are emptied completely and filled up with fresh water.

After the exhaust air has flowed through the two acidic scrubbing stages, which clean it of ammonia and dust, it enters the third purification stage. This consists of root wood packing with a thickness of 60 cm that serves to degrade odorous substances. In order to supply water to the microorganisms that are active here, it is necessary to constantly moisten the filter material.

Figure 2 shows the principle of the three-stage exhaust air treatment system in schematic form. Table 3 contains important process parameters.

Guarantee

The manufacturer provides a two-year guarantee that is only valid if the system is operated correctly. The installation and maintenance must be carried out by an accredited installer.

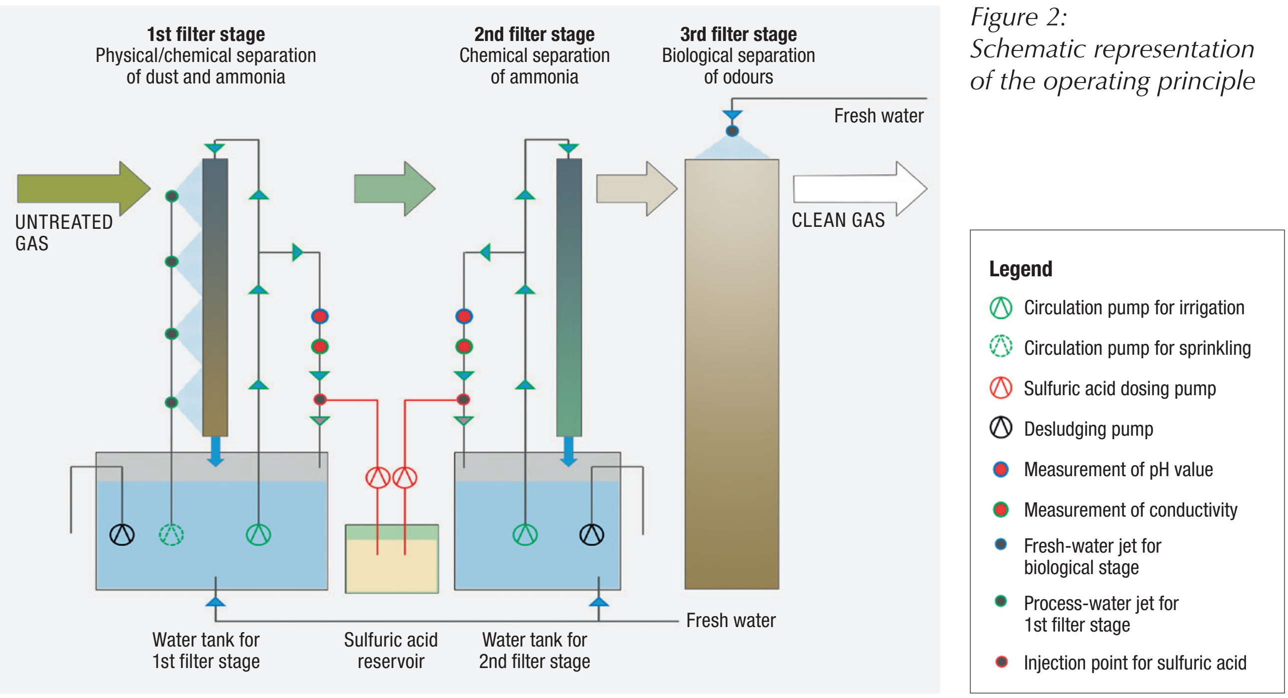

Figure 2: Schematic representation of the operating principle

Table 3:
MagixX-Pig+ exhaust air treatment system, company: Big Dutchman

	Criterion	Result/value
Description	Two-stage chemical exhaust air scrubber with constant irrigation and subsequent biological stage	
Suitability	Purification of exhaust air from litterless pig housing with overhead ventilation by reducing dust, ammonia and odours	
Quantification parameter for reference system – dimensions of PP150 packing and biological stage		
Filter wall 1 and 2	Length / height / depth	14.4 m / 2.0 m / 0.15 m
	Inflow area / packing volume	28.8 m^2 / 4.32 m^3
	Specific surface area of packing	270 m^2/m^3
	Minimum residence time at summer air flow rates (contact time)	0.16 s in each case
	Maximum load per unit area of filter	3,400 $m^3/(m^2\ h)$*
	Maximum load per unit volume of filter	22,685 $m^3/(m^3\ h)$*
Biological stage	Length / height / depth	14.4 m / 2.5 m / 0.60 m
	Inflow area / packing volume	36 m^2 / 21.6 m^3
	Minimum residence time at summer air flow rates	0.79 s
	Maximum load per unit area of filter	2,720 $m^3/(m^2\ h)$*
	Maximum load per unit volume of filter	4,530 $m^3/(m^3\ h)$*
Size of water reservoir		
Water tank 1	Length / width / height	15.4 m / 1.20 m / 0.80 m
	Water volume	14.78 m^3
Water tank 2	Length / height / depth	15.4 m / 0.50 m / 0.80 m
	Water volume	6.16 m^3
Irrigation (continuous)		
Filter wall 1	Irrigation volume in winter / summer	26.8 m^3/h / 30.0 m^3/h
	Irrigation density in winter / summer	0.93 $m^3/(m^2\ h)$ / 1.04 $m^3/(m^2\ h)$
Filter wall 2	Irrigation volume in winter / summer	19.2 m^3/h / 18.8 m^3/h
	Irrigation density in winter / summer	0.67 $m^3/(m^2\ h)$ / 0.65 $m^3/(m^2\ h)$
Presprinkling (intermittent)		
Filter wall 1	Volume flow rate per jet (according to manufacturer)	1.57 l/min
	Number of jets	112 pcs.
Desludging		
	Capacity of scrubbing water receiving reservoir 1	14.78 m^3
	Capacity of scrubbing water receiving reservoir 2	6.16 m^3
	Average desludging rate at an ammonia separation of 90 %, calculated	0.1125 $m^3/(AP \cdot a)$
	pH value of the 1st scrubbing water tank	< 4
	pH value of the 2nd scrubbing water tank	< 4
	Maximum conductivity	130 mS/cm
Reference farm for performed measurements (according to manufacturer)		
	Pig fattening house (batch rearing by compartment)	1,408 animal places
	Mean animal weight	Approx. 75 kg LW
	Maximum installed air output	98,000 m^3/h via 5 fans
	Pressure loss over exhaust air treatment system	Max. 80 Pa at 98,000 m^3/h of exhaust air
	Total pressure loss (stable + exhaust air treatment)	Max. 135 Pa at 98,000 m^3/h of exhaust air
	Max. air flow rate in summer acc. to DIN 18910	96,400 m^3/h for temperature zone II and 100 kg LW

* Because of the DLG measuring equipment that must be installed in the exhaust air duct in order to carry out the measurements, an additional pressure increase of 40 Pa was measured at the maximum air flow rate. After adjustment using the fan curve, it can be seen that the stated load per unit area/volume of the filter is reached at the maximum installed air output.

The measurements were performed on a reference system in Aurich. A shortened testing scenario was arranged as the exhaust air treatment system is based on a system certified according to the Cloppenburg guidelines. Testing included one summer and one winter measurement. As the tested system was a prototype system, it was not possible to conduct a survey of owners of the same model of exhaust air treatment system during the testing period.

The reference stable used for the measurements housed some 1,408 pigs for fattening. The air was extracted from the animal area via overhead vents by fans before being pooled in a central exhaust air collector duct and fed through the three subsequent cleaning stages of the exhaust air treatment system. For this purpose, two separate water-receiving reservoirs are provided for stage 1 and stage 2. The third stage (a biological filter for separating out odours) is supplied with fresh water. The ventilation technology was designed according to the specifications of DIN 18910. Accordingly, the maximum air flow rate should be approx. 96,400 m³/h. According to the manufacturer, the pressure loss over the stable and exhaust air treatment system is max. 135 Pa.

The measurements were performed from March to May 2012 (winter measurement) and from September to October 2012 (summer measurement).

Both water reservoirs were cleaned after 3 months. Together, the two water reservoirs had a total capacity of approx. 21 m³ and were kept at an electrical conductivity of max. 170 mS/cm in the DLG test. Safe operation of the system is guaranteed up to a conductivity of 130 mS/cm.

During the measurements, a record was made of the environmental conditions (temperature outside/inside, relative humidity outside/inside); on the measuring days for dust and odours, the following parameters were additionally documented:

- animal weights (estimated) and numbers of animals;
- fresh-water and electrical-energy consumption (meter readings);
- pressure loss over the system, as well as the pressure loss over the fan.

Furthermore, the measured values recorded by the manufacturer in the electronic operating log were checked for plausibility.

The following parameters were used to assess the exhaust air treatment system:

Dust

Sampling was carried out according to VDI Guideline 2066, Part 1 and according to DIN EN 13284-1. For this purpose, an isokinetic sampling system according to Paul Gothe was installed with a plane filter device (diameter: 50 mm). A round glass-fibre filter with a diameter of 45 mm was chosen as the separation medium. Analysis was performed using gravimetric determination of the dust load. The amount of fine dust was determined using a two-stage impactor in accordance with VDI 2066, Part 10 and DIN EN ISO 23210.

According to the DLG testing framework, the separation efficiency must be at least 70 %. This applies to both total dust and the PM_{10} and $PM_{2.5}$ fine dust fractions.

Ammonia

The ammonia measurements in the untreated-gas and clean-gas sections were carried out continuously throughout the investigation period based on DIN EN 15483 using a Gasmet FTIR analyser. In parallel to this, gas samples were taken in wash bottles on the measuring days and analysed according to VDI 3496, Part 1. The latter step served primarily to verify the measured values from the continuous measurement method. To prevent condensation, the sample gas lines were heated along their entire length. In order to check the ammonia concentration in the animal area, measurements were taken at animal height using Dräger tubes in regular inspections of the stable.

According to the current DLG testing framework, the NH_3 separation must not fall below a value of 70 %; i.e. it must be permanently above 70 %.

Odour

Sampling and analysis were carried out according to DIN EN 13725 with a TO 8 olfactometer from the company ECOMA GmbH. Odour samples were taken weekly from the untreated and clean gas and then analysed using olfactometry by a group of trained test subjects.

The criteria relevant to the test were the concentration of odorous substances and whether a typical untreated-gas odour was perceptible in the clean gas. With respect to the concentration of odorous substances, the DLG testing framework states that a value of 300 OU/m³ must not be exceeded in the clean gas. In addition, a typical untreated-gas smell must not be perceptible in the clean gas.

Aerosol emissions

Nitrogen-containing aerosols are stripped out of the filter walls of exhaust air treatment systems as NH_3 aerosols through droplet separation and entrained in the exhaust air flow. In this way, the nitrogen that is originally separated out is unintentionally returned to the environment.

During the measuring phase, the quantity of NH_3 aerosols was determined from the difference between filtered and unfiltered samples. Boric acid was used in this process. Multiple measurements were taken using impingement (absorption in wash bottles) to determine the quantity of aerosols under both summer and winter conditions.

Nitrogen balance

The nitrogen separation of the exhaust air treatment system was verified by nitrogen balancing on a two-weekly basis during the summer measurement period, taking account of the ammonia loads (in the untreated and clean gas), the aerosol emissions and the nitrogen compounds dissolved in the scrubbing water. This means that the nitrogen separated out from the ammonia in the untreated gas by the exhaust air treatment system was detected in the form of ammonium in the scrubbing water. The residual ammonia emissions in the clean gas were also determined.

Balancing the nitrogen flows within the system is important because:

- all relevant nitrogen compounds and their fates are determined.
- the nitrogen content of the sludge water is known and its fertiliser value is quantified.

Under the DLG testing framework, at least 70 % of the separated nitrogen must be recovered.

Nitrogen removal

The nitrogen removal indicates how many kilograms of nitrogen were removed from the system and can ultimately be removed from the scrubber in a manageable form. Insufficient nitrogen removal can, for example, point to incomplete collection of the sludge or a leakage. Also conceivable would be other processes that lead to the precipitation of nitrogen compounds as a result of insufficient moistening of the exchanger surfaces in the exhaust air treatment system.

Under the DLG testing framework, a nitrogen removal rate of at least 70 % must be maintained.

Consumption figures, environmental conditions and system load

The consumption of fresh water and electrical energy was determined by recording the corresponding meter readings. The acid consumption in the testing phase was determined using a weighing system (e.g. a precision balance). A record was made of the temperature and relative humidity outside and inside the stable during the measurements in order to document the environmental conditions.

In addition, on the measuring days for dust and odours, the parameters of the numbers of animals and the estimated animal weights were documented and the pressure losses over the system, or over the stable and exhaust air treatment system, were recorded by differential pressure measurement. Furthermore, the measured values recorded on the system in the electronic operating log were checked for plausibility.

Operational reliability and durability

The operational reliability and durability section assessed and documented any faults affecting the overall system or technical components during the testing period. In addition, an evaluation was made of any corrosion that occurred and of the durability in continuous operation.

Operating instructions, operation and working time requirements, maintenance requirements

The operating instructions were assessed from the user’s perspective. For the operating instructions, special emphasis is placed on functional description of the system, on attention to detail in the description, including in its illustrations, and on clear presentation of regular maintenance work.

In the operation and working time requirements section of the test, an assessment was made of whether it was necessary for the manufacturer to provide instruction during commissioning and of the requirements for regularly recurring inspections and work on a scheduled basis – daily, weekly, monthly, etc. – or in the event of faults that occur.

In terms of the maintenance requirements, an assessment is made of the servicing intervals and their specifications.

Documentation

In general, the electronic operating log is intended to record the following parameters:

- pressure loss over the system,
- air flow rate in m³/h,
- pump operating time and flow volumes (circulation, desludging),
- total fresh-water consumption by the system,
- absolute desludging rate,
- untreated- and clean-gas temperature,
- pH value and conductivity in all scrubbing stages,
- electrical power consumption of the exhaust air treatment system.

Furthermore, a record is to be made of spray pattern inspections, maintenance and repair times and calibrations of the pH probes. Evidence must be provided of the acid consumption (electronically or manually).

This data serves to prove the correct operation of the exhaust air treatment system and was checked on the MagixX-Pig+ exhaust air treatment system.

Environmental safety

The environmental safety section of the test included an assessment of any supplies (e.g. acids) required for operating the system, of the material recycling of any operating waste that arises (e.g. the desludged water), and of the removal and disposal of system components. Further, the areas of responsibility under which these aspects fall was also examined.

Safety aspects

In order to assess the system’s safety, a check was made of the system’s conformity with the currently applicable requirements in the areas of fire and occupational safety.

As this is a recertification of the Big Dutchman MagixX-Pig+ system, which has already been certified according to the Cloppenburg guidelines, a shortened measurement programme (winter measurement) was initially arranged following consultation with the DLG testing board. In addition, a repeat measurement (summer measurement) was carried out because of optimisation work carried out on the system in the interim.

Dust

Two total dust and two fine dust measurements (PM_{10}/ $PM_{2.5}$) were taken in each of the winter and summer measurements. Table 5

Table 4:
Typical composition and fluctuation range of the sludge water from the MagixX-Pig+ exhaust air treatment system

	Winter	Summer	
pH value (Water tank 1)	3.4 … 3.8	3.7 … 4.0	–
pH value (Water tank 2)	3.4 … 3.9	3.5 … 4.0	–
Conductivity (Water tank 1)*	136 … 193	93 … 143	mS/cm
Conductivity (Water tank 2)*	87 … 104	89 … 147	mS/cm
Nitrogen as nitrate (Water tank 1)	105 … 239	1,135 … 1,375	mg/l
Nitrogen as nitrate (Water tank 2)	33 … 204	282 … 415	mg/l
Nitrogen as nitrite (Water tank 1)	0 … 0.12	0 … 0.13	mg/l
Nitrogen as nitrite (Water tank 2)	0 … 0.1	0	mg/l
Nitrogen as ammonium (Water tank 1)	29,250 … 44,000	16,250 … 23,050	mg/l
Nitrogen as ammonium (Water tank 2)	16,400 … 24,250	16,000 … 21,400	mg/l

* Safe operation of the system is only guaranteed up to a conductivity of 130 mS/cm.

Table 5:
Measurement results for emissions reduction (dust) on the MagixX-Pig+ exhaust air treatment system

	Winter		Summer	
Date	**27 Mar 2012**	**16 Apr 2012**	**26 Sep 2012**	**18 Oct 2012**
Comments				
Ambient and boundary conditions				
Rel. outside humidity [%rH]	80	58	85	72
Ambient temperature [°C]	10.5	5.8	13.6	18.0
Untreated gas/clean gas humidity [%rH]	65/100	58/100	– –*	75 /100
Untreated gas/clean gas temperature [°C]	21.7/17.0	21.5/15.5	– –*	23.0/21.6
Number of animals in stable	1.528	1.536	1.498	950
Average animal weight [kg]	50	75	86	85
Air volume flow, total [m³/h]**	50,580	42,490	38,290	38,080
Pressure loss, scrubber stage 1–3 [Pa]	25	– –*	20	43
Pressure loss, stable + scrubber [Pa]***	> 50	– –*	> 50	> 70
Total dust (normalised)				
Concentration in untreated gas [mg/m³]	1.92	2.58	1.22	0.93
Concentration in clean gas [mg/m³]	0.15	0.45	0.07	0.06
Separation efficiency [%]	92.0	82.0	95.0	93.0
Fine dust (normalised)				
Untreated gas PM_{10}/$PM_{2.5}$ [mg/m³]	0.90/0.70	1.18/0.33	0.30/0.20	0.34/0.20
Clean gas PM_{10}/$PM_{2.5}$ [mg/m³]	0.10/0.03	0.1/0.01	0.03/0.01	0.05/0.01
Separation efficiency PM_{10}/$PM_{2.5}$ [%]	89.4/96.2	91.2/98.5	90.0/94.0	87.0/93.0

* No measurement data available
** Measurement data was recorded in the middle of the day
*** The measurement data was recorded without taking account of the influence of the velocity increase due to the fan's cross section, so the maximum pressure loss was higher (by approx. 10–50 Pa) than that measured by the DLG.

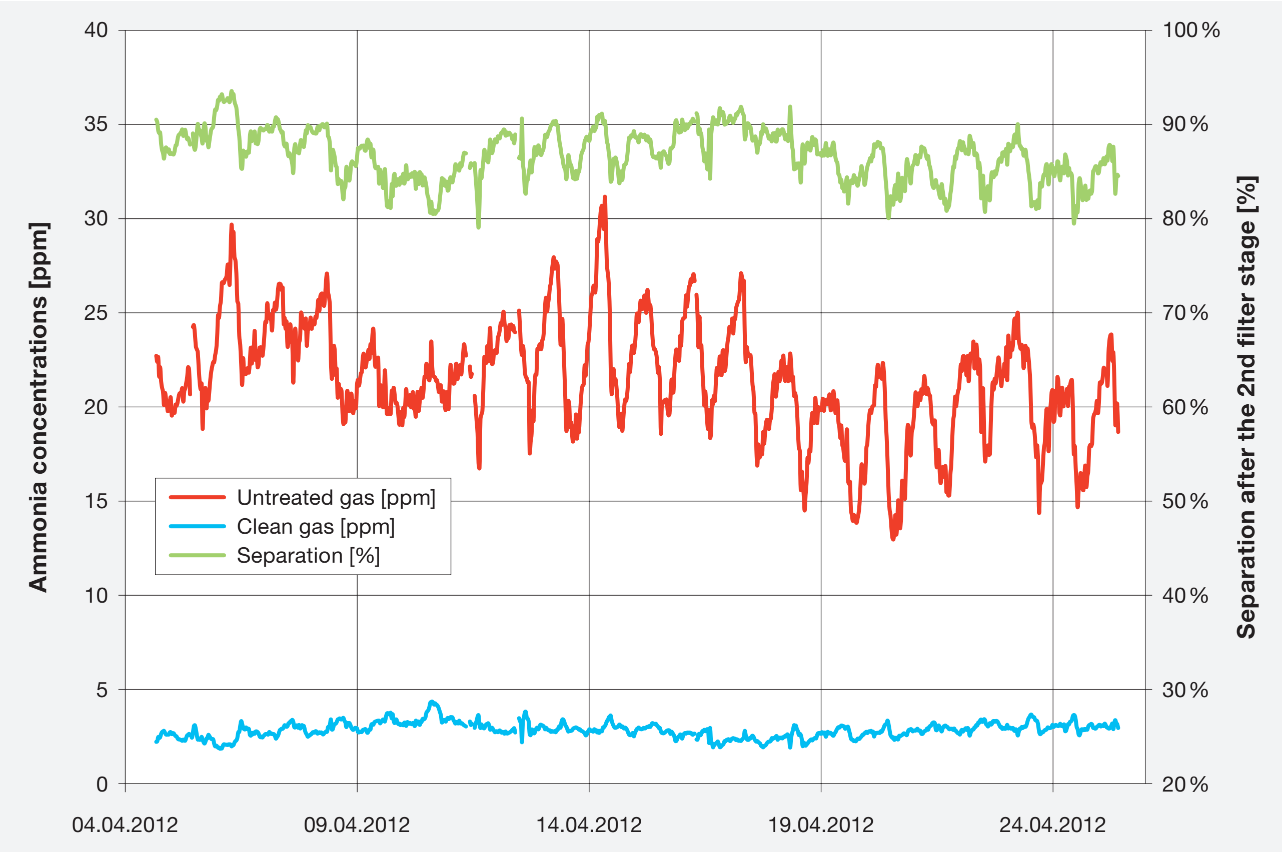

Figure 3:
Separation efficiency and variation in ammonia concentration in the untreated and clean gas during the winter measurements

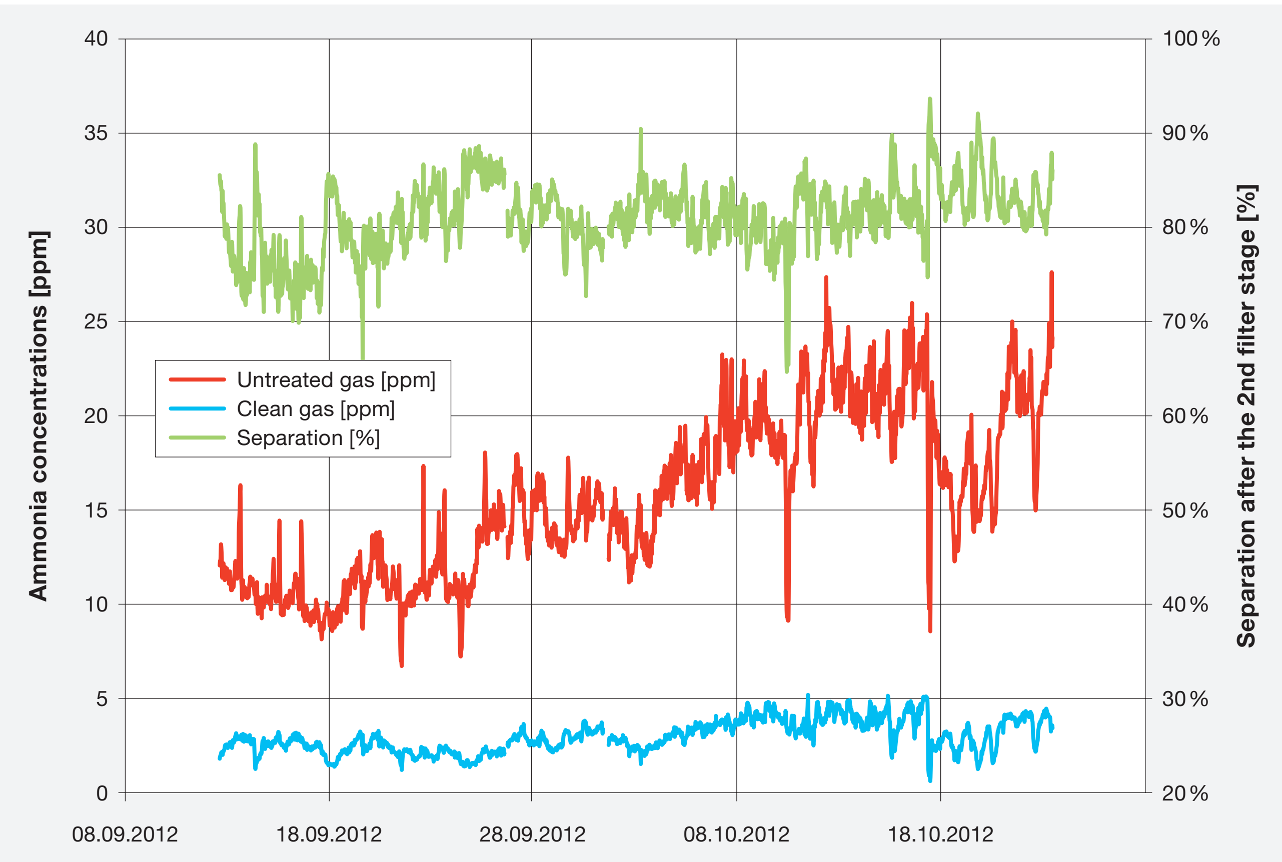

Figure 4:
Separation efficiency and variation in ammonia concentration in the untreated and clean gas during the summer measurements

shows that, in the winter measurement, an average of 87.0 % of the total dust was separated out. In the summer measurement, an average of 94.0 % of the total dust was separated out. The average separation efficiency for fine dust (PM_{10}) was 90.3 % in winter and 88.5 % in summer. For the fine dust ($PM_{2.5}$), an average of 97.4 % was achieved in winter and 93.5 % in summer. It was therefore demonstrated that the Big Dutchman MagixX-Pig+ three-stage exhaust air treatment system permanently achieves a separation efficiency greater than 70 % for the litterless pig housing method.

From experience, the scrubbing process can cause the formation of droplets (agglomeration) ranging from 2.5 to 10 µm in size, which can lead to a higher value for the PM_{10} particle fraction in the dust measurement with the impactor. The $PM_{2.5}$ particle fraction is less influenced by this effect. A greater separation efficiency is therefore calculated for this particle fraction than for the PM_{10} fraction.

Ammonia

In the untreated gas section, values of between 15 and 25 ppm were measured in winter. A maximum of 30 ppm was reached for a short time.

In summer, the range of the NH_3 concentration in untreated gas was between 5 and 20 ppm; towards the end of the fattening phase, values of up to 25 ppm were even reached for a short time on a few days. Regular checking of the NH_3 concentration at animal height using Dräger tubes showed no abnormalities. Effective ammonia separation is therefore ensured (Table 6) under the described operating conditions for the litterless pig housing method and when the system is operated correctly.

Figures 3 and 4 show the ammonia concentration and the separation efficiency. The brief drop in separation efficiency in the summer measurement on 19 September 2012 and on 10 October 2012 was caused by the manual activation of all fans for testing purposes. On average, 87 % of the ammonia was separated out by the two acidic filter stages in winter and 81 % in summer.

Table 4 shows that cleaning by just one acidic scrubbing stage is not sufficient. This is indicated by the concentration increase in water reservoir 2.

Odour

The results of the odour samples taken within the framework of the DLG testing method are shown in Table 7. A shortened measurement programme was carried out as the system is already certified according to the Cloppenburg guidelines and because the optimisation work subsequently performed on the system does not directly affect the odour separation. In the winter measurement, odour samples were initially taken on a total of four measuring days.

Because of the strong inherent odour of the biological filter (3rd scrubbing stage), untreated-gas concentrations of approx. 1,300 OU/m³ translated into clean gas concentrations of just 373 to 419 OU/m³, at which no untreated-gas odour was perceived in the clean gas. Within the framework of an additional measurement (summer measurement), the biological filter packing was replaced and the suitability of the odour stage was demonstrated through two measurements.

Based on these results and the certification according to the Cloppenburg guidelines, it can be assumed that the system provides

Table 6:
Measurement results for emissions reduction by the Big Dutchman MagixX-Pig+ system for ammonia and process data during the summer and winter measurements (selected daily averages)

	Winter		Summer		
	5 Apr 2012	**9 Apr 2012**	**17 Sep 2012**	**24 Sep 2012**	**2 Oct 2012***
Air-flow rate [m³/h]	31,870	40,520	61,440	76,180	52,590
Flow velocity** [m/]	0.31	0.39	0.59	0.73	0.51
Residence time** [s]	0.98	0.77	0.51	0.41	0.59
Load per unit area of packing** [m³/(m² · h)]	1,107	1,407	2,133	2,645	1,826
Load per unit volume of packing** [m³/(m² · h)]	3,689	4,690	7,111	8,817	6,087
Irrigation density FW1** [m³/(m² · h)]	0.97	0.95	1.09	1.08	1.02
Irrigation density FW2** [m³/(m² · h)]	0.67	0.67	0.65	0.65	0.66
Ammonia in untreated gas [ppm]	23.9	21.1	9.0	7.6	12.4
Ammonia in clean gas [ppm]	2.5	3.1	2.4	1.5	2.5
Ammonia separation efficiency [%]	87.3 %	85.2 %	73.8 %	80.6 %	80.1 %

* Values measured at 5 p.m.
** Calculated value

Table 7:
Measurement results for emissions reduction (odour) with the MagixX-Pig+ exhaust air treatment system

	Summer	
Date	**11 Oct 2012**	**23 Oct 2012**
Ambient and boundary conditions		
Rel. outside humidity [%rH]	68	80…95
Ambient temperature [°C]	10.0	13.0
Untreated gas/clean gas humidity [%rH]	82/100	76/100
Untreated gas/clean gas temperature [°C]	22.0/19.0	24.4/20.3
Number of animals in stable	951	794
Mean animal weight [kg]	100	85
Air volume flow, total [m³/h]	23,830	23,380
Pressure loss, scrubber [Pa]	18	29
Pressure loss, stable + scrubber [Pa]*	> 40	> 50
Odour**		
Untreated gas [OU/m³]	742	1,700
Clean gas [OU/m³]	271	283
Odour of untreated gas perceptible in clean gas?	No	No

Table 8:
Mean values from the aerosol determination

	Winter
Ammonium sulfate [mg/Nm³]	0.41

Table 9:
Power consumption values during the measurement period on the Big Dutchman system

Pumps (circulation)	
– in winter	70.8 kWh/day or 16.9 kWh per animal place and year
– in summer	74.5 kWh/day or 22.9 kWh per animal place and year
Fans (total consumption)***	
– in winter	83.6 kWh/day or 19.9 kWh per animal place and year
– in summer	61.6 kWh/or or 20.8 kWh per animal place and year

* The measurement data was recorded without taking account of the influence of the velocity increase due to the fan's cross section, so the maximum pressure loss was higher (by approx. 10–50 Pa) than that measured by the DLG.

** Geometric means

*** The fans were regulated by a multistep controller during the measurement period; the installation position of the DLG's instrumentation during the measurement period caused an additional pressure loss of up to 40 Pa in the untreated-gas duct at the maximum air flow rate. The actual power consumption of the fans is therefore slightly lower.

permanent odour separation (compliance with the criteria of 300 OU/m³ and no perceptible untreated gas).

Because of the cool climate and the low number of animals in the summer measurement, the odour samples were taken at only approx. 25 % of the designed air-flow rate.

Aerosol emissions

In order to determine the ammonium sulfate emissions as aerosol emissions following the second scrubbing stage, a further accumulation was carried out in the winter measurements using boric acid solution in parallel to the accumulation in sulfuric acid wash bottles.

The quantities of NH_3 aerosols can be derived from the difference between the two samples and are summarised in Table 8.

Nitrogen balance

It was not possible to determine the recovery rate from the loads in the winter measurement, as dust and salt residues had been deposited on the scrubber walls and water fittings in the pressure chamber as a result of return-flow effects. Overall, these quantities were too significant to allow representative nitrogen balancing to be carried out. Within the framework of the repeat measurement (summer measurement), nitrogen balancing was performed under similar conditions, albeit with the pressure chamber cleaned. Depositions were not taken into account for the balance. Three balances were determined in the summer measurement, yielding a mean value 75 %. The results show that, as scrubber operation increases, the nitrogen content in the water reservoir is influenced by deposition and salt precipitation. In order to rule out return flows of this kind in future, the following measures were called for:

- synchronous driving of fans;
- even distribution of fans over the entire length of the scrubber;
- minimum distance of 4 m between fan and first scrubbing wall (recommendation).

Nitrogen removal

The separation with respect to nitrogen (nitrogen removal) was a mere 56.5 % because of the large quantities of nitrogen deposition outside of the scrubbing-water receiving reservoir. The nitrogen removal is not assessed in this report as it was not covered by the testing method before completion of the measurements on the Big Dutchman system.

Consumption figures, environmental conditions and system load

Water consumption

Fresh water was fed into the system in order to balance out the water losses due to desludging and evaporation. The two water tanks of stage 1 and 2 are structurally separate from one another. However, the electrical conductivity of the second water tank rises more slowly than in the first water tank.

In the winter measurement, an average of 2.8 m³/d of fresh water is consumed, which corresponds to an annual consumption of 0.72 m³/(AP · a). During the summer measurement, 2.12 m³/d or 0.67 m³/(AP · a) was consumed. Of this, the water required to irrigate the biological filter accounted for 0.51 m³/h or 0.12 m³/(AP · a) in winter and 0.36 m³/h or 0.12 m³/(AP · a) in summer.

The fact that higher consumption was measured in winter than in summer is primarily due to

Table 10:
Acid consumption values on the Big Dutchman exhaust air treatment system

Filter stage 1 and filter stage 2	
– in winter	29.4 kg H_2SO_4 per day or 7.0 kg per animal place and year
– in summer	24.1 kg H_2SO_4 per day or 8.2 kg per animal place and year

Table 11:
Satisfaction of requirements for the electronic and manual operating log of the MagixX-Pig+ exhaust air treatment system

	Completely met	Partially met	Not met	Comments
Pressure loss over the exhaust air cleaning system	X			Electronic differential pressure capsule for determining the pressure loss over the exhaust air treatment system and also over the biological stage
Air flow rate of exhaust air treatment system	X			Determined from pressure loss and calibration curve (“Dynamic Air” method)
Pump operating time for 2 circulation pumps	X			Determined from the energy meters and pump pressure
Irrigation intervals and irrigation quantity		X		Determined from pump characteristic curve and counterpressure; the filter-wall irrigation is operated continuously
Total fresh water consumption of the scrubber	X			Logged using a water meter with pulse generator
Quantity of desludged water	X			Determined from the reservoir level
Untreated- and clean-gas temperature	X			Both temperatures are recorded
Spray-pattern check	X			Evidence provided via manual operating log
Maintenance and repair times	X			Evidence provided via manual operating log
Compliance with pH value and conductivity in scrubbing water	X			pH value and conductivity are recorded and stored separately for the two scrubbing stages
Calibration of pH value sensors	X			Evidence provided via manual operating log
Evidence of acid consumption		X		Evidence provided via purchasing documents, which are filed in the manual operating log
Electrical power consumption of exhaust air treatment system	X			Recorded via suitable electricity meters and stored

the relatively cool temperatures encountered in summer, while the outside temperature in winter was relatively high.

The scrubbing water is completely replaced when a value of 130 mS/cm is reached or, at the latest, after a period of three months. The measurement data is shown in Table 2.

Electrical energy consumption

The continuously operated circulation pumps make up the largest share of the electrical power consumption of the exhaust air treatment system. In the stable area, the largest consumers were the fans, which had to be of a larger size than for simple stable ventilation because of the additional pressure loss over the exhaust air treatment system. Over the measurement period, the values listed in Table 9 were recorded using electricity meters.

The increased power consumption in winter is due, on the one hand, to the greater number of animals in the stable and therefore the higher air flow rate and, on the other, to the very mild outside temperatures. In contrast, the ambient temperatures during the summer measurement were relatively low.

The installation position of the DLG's instrumentation during the measurement period caused an additional pressure loss of up to 40 Pa in the untreated-gas duct at the maximum air-flow rate. The actual power consumption of the fans is therefore slightly lower.

Other consumption figures

To ensure safe operation, the system is equipped with automatic acid metering. The acid-metering device is strictly required for correct operation. The pH value in the scrubbing water and/or in the filter wall was regulated with this acid metering system. The pH value in the two scrubbing stages was configured to less than 4. During the measuring phases, the acid-consumption figures shown in Table 10 were recorded as mean values. The values relate to the consumption of 100 % sulfuric acid. During the measurements, 96 % sulfuric acid was added to the reference system.

Because of implausible measurement data during the winter measurements, the ammonia loads entered into the system for the period 4–24 April 2012 were used to calculate the acid consumption. The consumption data is valid for 84 % ammonia separation.

Safe system operation with the stated efficiencies is possible only with correctly operated pH-value regulation.

Operational reliability and durability

In the testing period, no significant faults were identified in the system technology, and no significant damage or signs of wear occurred anywhere on the exhaust air treatment system during the test.

Insofar as could be observed within the duration of the test, the corrosion protection of the individual system components appeared to be sufficiently durable. The substructure and side walls of the system were manufactured from acid-resistant and sealed concrete.

The substructure is not part of the exhaust air treatment system and is erected by a subcontractor. The operator is strongly advised to have the necessary protective coating applied to the concrete by a specialist company and to obtain a guarantee.

Operating instructions, operation and working time requirements, maintenance requirements

The operating instructions are sufficiently precise and explain the system's mode of operation in general terms. In conjunction with the documentation, the operator is told what work they must carry out on the system on a daily, weekly and annual basis.

In order to control the system, it is necessary to receive instruction from the manufacturer and to familiarise oneself with the operating instructions. However, after initial start-up and a sufficient running-in phase, the system's operation can be viewed as easy, since the exhaust air treatment system is fully automatic in normal operation. All that is required is a daily check of the operating data and the functional reliability (e.g. spray pattern) and a weekly check of the overall exhaust air treatment system. In the event of error messages from the controller, the operating instructions provide instructions for checking the relevant system components in each instance. To simplify operation and reduce the working time requirements, it is advisable to enter into a maintenance contract with the manufacturer.

If a maintenance contract is entered into, the maintenance work set out in the maintenance schedule is carried out twice a year. Any defects that are discovered and spare parts that are replaced are recorded in a maintenance log. In the regular maintenance checks, a record is made of the ammonia concentrations in the untreated and clean gas, the pressure measurement, and the pump pressures. In addition, the pH value measuring device is calibrated and the pH value distribution over the length of the reservoir is measured. The state of the filter materials and pumps is inspected and the electronic operating log is checked.

The pH value sensors must be calibrated by the operator regularly, and a record must be made in the operating log of these calibrations, along with their time and date. Without proven calibration, correct operation of the system is not possible.

Documentation

The electronic operating log permits seamless recording, every half an hour, of the data required for safe operation of the system. The system's manufacturer records the data and stores it for 5 years. This data can be read by the farmer or the manufacturer via a USB interface and transferred to any common spreadsheet program. The recorded data is described in detail in Table 11.

Environmental safety

The desludged water from water tanks 1 and 2 (pH < 4) must be stored temporarily in a separate sludge container. The period of storage is based on the specifications of the Fertiliser Ordinance (DüMV) for the storage of liquid manure. The sludge container must be suitable for the sludge water (pH value < 4). In this respect, the administrative instructions for substances harmful to water must be adhered to on a country-specific basis. Immediately before application to agricultural land, the sludge water can be mixed with liquid manure outside of the stable. Table 4 shows the composition of the scrubbing water. As the substances in use are substances harmful to water within the meaning of the Water Resources Act (WHG), corresponding requirements must be adhered to. In this regard, country-specific requirements must be complied with, e.g. the Ordinance on Facilities Handling Substances Harmful to Water (VAwS).

According to the manufacturer, the removal and disposal of other system components can be carried out by accredited recycling facilities.

Acid is required for the system's operation. The acid's handling is explained by the manufacturer in operating instructions and is the responsibility of the operator.

Safety aspects

The MagixX-Pig$^+$ exhaust air treatment system is equipped with a safety kit (gloves, goggles, apron and eye bath) for handling sulfuric acid.

The sulfuric acid drum (1 m^3) must be either positioned on a drip tray or used in a double-walled container.

The occupational safety of the described exhaust air scrubber from the company Big Dutchman has been examined and evaluated by experts from the Social Insurance for Agriculture, Forestry and Horticulture (SVLFG) and the German Centre for the Testing and Certification of Agricultural and Forestry Technology (DPLF). From a safety perspective, there are no concerns about using the system.

Summary

The MagixX-Pig$^+$ exhaust air treatment system from the company Big Dutchman GmbH, with the PP150 packing that is used here, is suitable for reducing emissions of dust, ammonia and odours from the exhaust air flow from litterless pig housing methods if the ventilation is designed according to DIN 18910 and the described process parameters are adhered to for the separation of ammonia (separation efficiency ≥ 70 %) and dust (separation efficiency ≥ 70 %) and for the minimisation of odours (to < 300 OU/m^3 without an odour of untreated gas in the clean gas). The two-stage chemical scrubber with a biological cleaning stage is suitable for stable systems with overhead air ventilation.

Further information

Further tests on exhaust air treatment systems are available to download at **www.dlg-test.de/stallbau**. The DLG Committee for Animal Production Technology has published a working paper (instruction leaflet) entitled "DLG Working Paper: Ventilation" on the topic of ventilation in pig housing. This is available free of charge in PDF format at **www.dlg.org/technik_tierproduktion.html**. Further DLG instruction leaflets are available from the DLG committees for pig production at www.dlg.org/schweineproduktion.html and for animal welfare at **www.dlg.org/tiergerechtheit.html**.

Test execution

DLG e.V.,
Test Center
Technology and Farm Inputs,
Max-Eyth-Weg 1,
64823 Groß-Umstadt

DLG Testing Framework

SignumTest "Exhaust air cleaning systems for livestock farming installations" (revised 10/2010)

Field

Renewable energies

Project manager

Dipl.-Ing. S. Gäckler

Test engineer(s)

Dipl.-Ing. (FH) Tommy Pfeifer*

Testing board

Test accompanied by
Dr Jochen Hahne, TI Braunschweig; Friedrich Arends, LWK Niedersachsen; Andreas Schlichting, TÜV Nord Hamburg

In an advisory role
Gerd Franke, LLH Kassel; Prof. Eberhard Hartung, University of Kiel; Ewald Grimm, KTBL Darmstadt

Administration
Representatives of the District of Cloppenburg

Laboratory and emissions measurements

LUFA Nord-West, Jägerstraße 23-27, 26121 Oldenburg

* Reporting engineer

The DLG

In addition to conducting its well-known tests of agricultural technology, farm inputs and foodstuffs, the DLG acts as a neutral, open forum for knowledge exchange and opinion-forming in the agricultural and food industry.

Around 180 full-time staff and more than 3,000 expert volunteers develop solutions to current problems. More than 80 committees, working groups and commissions form the basis for expertise and continuity in technical work. Work at the DLG includes the preparation of technical information for the agricultural sector in the form of instruction leaflets and working documents, as well as contributions to specialist magazines and books.

The DLG organises the world's leading trade exhibitions for the agriculture and food industry. In doing so, it helps to discover modern products, processes and services and to make these transparent to the public.

Obtain access to knowledge advancement and other advantages, and collaborate on expert knowledge in the agricultural industry! Please visit http://www.dlg.org/membership_agriculture.html for further information.

The DLG Test Center Technology and Farm Inputs

The DLG Test Center Technology and Farm Inputs in Groß-Umstadt sets the benchmark for tested agricultural technology and farm inputs and is the leading provider of testing and certification services for independent technology tests. With the latest measurement technology and practical testing methods, the DLG's test engineers carry out testing of both product developments and innovations.

As an EU-notified test laboratory with multiple accreditations, the DLG Test Center Technology and Farm Inputs provides farmers and practitioners with important information and decision-making aids, in the form of its recognised technology tests and DLG tests, to assist in the planning of investments in agricultural technologies and farm inputs.

2010-00157

DLG e.V.
Test Center Technology and Farm Inputs
Max-Eyth-Weg 1 · 64283 Groß-Umstadt
Telephone +49 69 24788-600 · Fax +49 69 24788-690
tech@DLG.org · www.DLG.org

Download all DLG test reports free of charge at: www.dlg-test.de!