DLG TEST REPORT 7561

GrainProteinTech Climate Control & Air Treatment Germany GmbH

Exhaust air purification system Munters Reventa Lavamatic

for broiler chickens

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GESAMT-PRÜFUNG
GRAINPROTEINTECH MUNTERS REVENTA LAVAMATIC FÜR MASTHÄHNCHEN
DLG-Prüfbericht 7561

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overview

The "DLG-APPROVED COMPLETE TEST" test mark is awarded to
technology products that have successfully completed a comprehensive DLG agricultural utility value test according to independent and recognized evaluation criteria.

In this test, all essential product characteristics from a practitioner's perspective are neutrally evaluated. The test includes investigations on test benches and under various operating conditions; in addition, the test object must demonstrate its effectiveness in practical testing in operational use. The test conditions and procedures, as well as the evaluation of the test results, are defined by an independent testing commission within a test framework and are continuously adapted to recognized technical standards as well as scientific and agricultural findings and requirements. Successful testing concludes with the publication of a test report and the award of the test mark, which is valid for five years from the date of award.

To obtain the certification mark, the "Lavamatic" exhaust air purification system from GrainProteinTech Climate Control & Air Treatment Germany GmbH was tested for its suitability for reducing dust and ammonia emissions from the exhaust air stream of a broiler farm using the heavy-duty fattening method. The basis for the test is a ventilation system design in accordance with the German Animal Welfare Ordinance (TierSchNutztV), which stipulates a maximum air flow rate of 4.5 m³ per kilogram per hour for broiler chickens kept on the floor.

According to the current DLG test framework, in order to prove the emission

At least 70% of total dust and particulate matter (PM10) and at least 70% of ammonia must be reduced. A nitrogen capture (N removal) of at least 70% must be demonstrated within a nitrogen balance, and the aerosol discharge must not exceed 0.5 mg N/m³ in the clean gas.

The test was conducted at a broiler farm with a Lavamatic unit, where only a partial flow of the exhaust air was cleaned. The test was performed on a Lavamatic XL with an exhaust air flow rate of 110,000 m³/h. In addition to the tested system with 110,000 m³/h, systems with 55,000 m³/h and 27,500 m³/h are also available.

The stated minimum requirements were met and, in some cases, exceeded. Thus, the Lavamatic was certified for broiler production according to the DLG test framework.

Assessment – in brief

The exhaust air purification system “Lavamatic” from the company GrainProteinTech Climate Control & Air Treatment Germany GmbH is a single-stage, chemically operating exhaust air scrubber for the separation of dust and ammonia from litter-filled broiler farming using heavy-duty fattening processes.

The Lavamatic operates on the pressure principle. The minimum distances are given in Table 2. If the minimum distances are not maintained, a uniform flow with the specified separation performance can no longer be guaranteed. The investigations were carried out on a stable system using the pressure principle.

The raw gas was extracted from the barn area as a partial stream via fans and forced through a purification stage. All fans are controlled in groups and regulated according to the outside temperature. The purification stage consists of a continuously operating washing drum rotating in a water reservoir with a pH of ÿ 3.

The exhaust air flow is passed through the drum. Due to the constant rotation of the drum, it is always kept moist and can retain ammonia and dust particles.

In order to reliably guarantee the separation performance described in the DLG test report, a pH value of ÿ 3 and a maximum conductivity of the wash water of 170 mS/cm must be maintained. The filter volume load must not exceed 8,700 m³/(m³*h), the drum speed must be at least 3 revolutions per minute (rpm), while the water in the storage tank must not sink below 30 cm and the minimum immersion depth of the drum 20 cm

must be.

In the test, the exhaust air purification system achieved a minimum separation efficiency for total dust of 88.9% in winter and 81.1% in summer. At least 74.0% of PM10 particulate matter was removed in winter and at least 72.3% in summer. Through chemical reactions (formation of ammonium sulfate), at least 83.0% of ammonia was removed in winter and at least 77.4% in summer. Nitrogen was removed from the system via the wash water by 75.6% in summer and 92.2% in winter (N removal). Aerosol discharge measurements remained unremarkable and met the requirements of the DLG test framework. The results are summarized in Table 1.

Since in the light mast up to 33 days the emissions according to VDI 3894-1 for ammonia and dust are safely are below the specified emission factors for broiler farming (barn farming up to 42 days) and the expected emission mass flow is lower, the tested exhaust air purification system can also be used in a broiler farm with light fattening.

Table 1:

Overview of results of the Lavamatic exhaust air purification system

Test criterion	Result	Evaluation*
Results of emission measurements		
Total dust (gravimetric)		
Winter (8 measurements), minimum separation efficiency [%][1],[2]	88.9	■■■■□
Summer (4 measurements), minimum separation efficiency [%][1],[2]	81.1	■■■■□
Fine dust PM10 (gravimetric)[3]		
Winter (4 measurements), minimum separation efficiency [%][1],[2]	74.0	■■■□□
Summer (4 measurements), minimum separation efficiency [%][1],[2]	72.3	■■■□□
Fine dust PM2.5 (gravimetric)[3]		
Winter (4 measurements), minimum separation efficiency [%][1],[2]	84.0	kB
Summer (4 measurements), minimum separation efficiency [%][1],[2]	81.4	kB

Table continued on page 4

Test criterion	Result	Evaluation*
Results of emission measurements		
Ammonia (2 runs each in winter and summer, measured continuously)		
Winter, minimum separation efficiency [%][1]	83.0	■■■■□
Summer, minimum separation efficiency [%][1]	73.8	■■■□□
N removal		
Winter [%]	92.2	■■■■■
Summer [%]	79.6	■■■□□
Consumption measurements (average values per day or per animal place and year)[4],[5],[6]		
Fresh water consumption		
Winter [m³/d]/[m³/(TP a)]/[m³/(TP a)]	1.4/0.02/0.01	kB
Summer [m³/d]/[m³/(TP a)]/[m³/(TP a)]	2.9/0.04/0.02	kB
Annual mean [m³/d]/[m³/(TP·a)]/[m³/(TP·a)]	2.2/0.03/0.02	kB
Blowdown volume[7]		
Annual mean [m³/d]/[m³/(TP·a)]/[m³/(TP·a)]	0.039/0.001/0.001	kB
Acid consumption (based on 96% sulfuric acid)		
Winter [kg/d]/[kg/(TP a)]/[kg/(TP a)]	9.2/0.10/0.07	kB
Summer [kg/d]/[kg/(TP a)]/[kg/(TP a)]	7.5/0.09/0.06	kB
Annual mean [kg/d]/[kg/(TP·a)]/[kg/(TP·a)]	8.4/0.10/0.06	kB
Electrical energy consumption		
Exhaust air purification		
Winter [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	16.1/0.18/0.12	kB
Summer [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	19.7/0.23/0.15	kB
Annual average [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	17.9/0.21/0.14	kB
fans		
Winter [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	47.0/0.53/0.46	kB
Summer [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	163.6 /1.95/1.68	kB
Annual average [kWh/d]/[kWh/(TP a)]/[kWh/(TP a)]	105.3 /1.24/1.07	kB

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* The DLG testing framework provides the following evaluation options in the evaluation schemes:
■■■ or better = meets, exceeds or significantly exceeds the specified DLG standard, ■■ = complies with legal Requirements for marketability, ■ = failed; kB = no assessment

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1 The minimum dust removal efficiency is defined as the lowest value measured during the measurement period. The minimum removal efficiency for ammonia is the average removal efficiency minus the standard deviation.

2 Only those chimneys were sampled that were active at the time of measurement.

3 Experience has shown that the washing process can lead to the formation of droplets in the size range 2.5 to 10 µm, which Cascade impactors can cause an increase in the PM10 particle fraction . The PM2.5 particle fraction is less affected by this effect. Therefore, a higher separation efficiency is calculated for this particle fraction than for the PM10 fraction.

4 Due to partial flow treatment at the reference plant, the determined consumption data can only be compared to other Compare systems. During the test period, 100% of the exhaust air from the housed animals was cleaned in winter, and 94% in summer. Thus, almost the entire exhaust air flow from the animals was conveyed through the exhaust air purification system. The media consumption was therefore calculated based on the average number of housed animals of 32,500. The figures refer only to partial exhaust air flow treatment. With full filtration (100% exhaust air treatment), higher consumption is expected.
expected.

5 The animal-place-related consumption data were given, on the one hand, based on washer operation 365 days per year and – with the exception of fan power consumption – on the other hand, based on washer operation 240 days per year (including service times and washer start from the 10th day of fattening). This allows for a better comparison with other systems.

6 Some of the measurements were conducted before the procedural changes. Therefore, some measured values are not or only partially meaningful. Only those measured values that can be considered representative are shown.

7 During the measurement period, no blowdown was carried out. In order to estimate the actual wastewater consumption, a Annual consumption calculated.

The product

Manufacturer and applicant

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Product:

Munters Reventa Lavamatic exhaust air purification system for broiler chicken farming

Description and technical data

The "Lavamatic" exhaust air purification system is a single-stage system with a chemical stage for purifying exhaust air from broiler farms using the heavy-duty fattening process. This system operates using a pressure process. The feed used is

Standard feed is used.

The exhaust air is extracted from the animal area by a total of four fans and conveyed directly to the cleaning stage.

A drum washer operates here, constantly rotating at three revolutions per minute. On the raw gas side, the drum is immersed in the water reservoir (wash water, process water) and wets the packing elements installed in the drum with wash water. To ensure a pH value of ÿ 3 in the wash water, 96% sulfuric acid is added. The exhaust air flows through the rotating

The air then passes through a 90° bend into the vertical exhaust stack and flows upwards to the outside. Each supply air duct contains a measuring fan to record the volume flow.

In the drum washer, coarse and fine dust particles

Parts are washed out in the process water and later removed from the system through blowdown and basic cleaning. Gaseous ammonia reacts with sulfuric acid wash water to form ammonium sulfate. The increasing salt content leads to an increase in the conductivity of the wash water. At a maximum conductivity of 170 mS/cm, a portion of the water reservoir is automatically blown down and removed from the system.

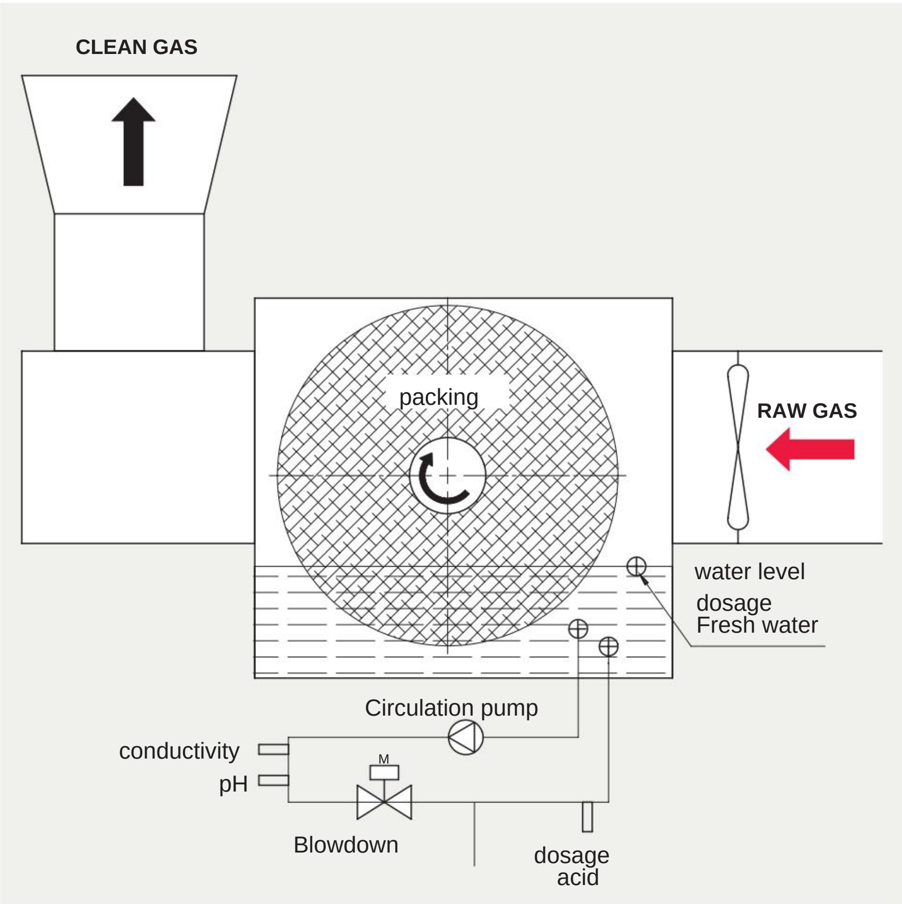

Image 2:

Functional description Lavamatic (principle sketch)

By rotating the

Washing drum, the

Packing material partially cleaned.

A scraper located in the upper part of the washing drum

mounted, ensures that larger particles are removed from the

Outside of the drum

At the same time, the scraper serves to seal

To achieve the described separation performance, this cleaning system does not require a circulation pump, as the drum moistens itself through its rotation.

The large specific surface area of the packing serves to

Enlargement of the contact area between stable exhaust air and

Washing water for effective

Separation of ammonia and dust. Due to the structure

of the exhaust chimney (90° bend

upwards) nitrogen-containing aerosols can be retained and resulting water losses can thus be reduced.

The optimal pH value is ÿ 3. Compliance with this value must be automatically monitored and stored as a half-hourly average in the electronic operating log (EBTB). If the maximum permissible pH value is exceeded,

Acid is added to the

Process water is added, which causes the pH value to drop again.

The specified structure of the Lavamatic between the supply air and exhaust air module is intended to ensure water droplets (aerosols) are retained in the system. A droplet separator is not provided.

Of the four fans, fans No. 1 and 2 were initially

(Group A) was run up to 100%, then fans No. 2 and 4 (Group B) were run up to maximum. Both groups were controlled by speed. The design of the exhaust air purification system must not exceed a maximum filter volume load of 8,700 m³/(m³ h).

To avoid excessive salt buildup, which would lead to salt precipitation and thus malfunctions, the water must be blown down at regular intervals. Blow-down occurs automatically depending on the salt content of the wash water, i.e., the electrical conductivity. The blown-down wash water is replaced with fresh water.

The conductivity of the wash water is limited to 170 mS/cm.

To prevent an unacceptable increase in the pH value in the

To prevent washing water during operation, if the maximum permitted

To adjust the pH, acid is added using an acid dosing system, resulting in an immediate drop in the pH. Therefore, sufficient acid must be available for proper operation.

For stable system operation, in addition to the filter volume load and pH and conductivity values, the process parameters for drum operation must also be maintained. The rotation speed must not fall below 3 revolutions per minute, and the water level in the feed tank must be maintained at a minimum of 30 cm, with the drum immersion depth being 20 cm.

Since plant operation also leads to increased water evaporation, the fresh water input and blowdown volume must be recorded and stored in the electronic operating log (EBTB). The water level is monitored

via an electronic level sensor, which also ensures that the drum does not run dry and that fresh water is supplied up to the standard fill level.

level is replenished.

The drum must be thoroughly cleaned after each mast passage. In individual cases, cleaning may be necessary sooner.

In this case, the operator is informed that the backpressure across the drum has reached the limit of 250 Pa and that blowdown is required. An alarm message is generated in the control system and the EBTB, and the operator is prompted to perform a manual blowdown.

The process is shown schematically in Figure 2. Important process parameters can be found in Table 2.

Warranty

The manufacturer provides a two-year warranty, which assumes proper operation of the system and does not apply to wear parts. This warranty is subject to installation supervision by the manufacturer and maintenance according to the maintenance schedule in the operating manual.

Table 2:

Process parameters of the exhaust air purification system

	feature	Result/Value
Description	single-stage, chemical cleaning system	
fitness	Purification of exhaust air from broiler farming when using standard feed	
	by reducing dust and ammonia	
Dimensioning parameters of the reference system according to the manufacturer's specifications (continuously operated)		
	Distance animal area/fan (pressure operation) [m]	1.0
	Distance fan/drum center (pressure operation) (m)	1.9
	maximum air volume flow (partial flow treatment) [m^3/h]	110,000
	Clean gas outlet area at the reference plant [m^2]	5.1
Chemical cleaning stage	Number of drum modules [pcs]	4
	Length/Outer diameter/Inner diameter [m/m/m]	1.815/1.7/0.8
	free inflow area [m^2]/active filter volume [m^3]	15.33/11.8
	Min. residence time at summer air rates [s]	approx. 0.06
	maximum flow velocity [m/s]	2.00
	Immersion depth of the drum/water level [mm]	200/300
	maximum filter volume load [m^3/(m^3*h)]	8,700
	Packing type [-]	NC 20-27
	Specific surface area of the packing [m^2/m^3]	125
	Gap level [%]	> 97
	Drum speed [rpm]	3
	Direction of rotation [-]	immerses in the water on the raw gas side
	Distance drum/chimney start [m]	1.20
Blowdown	Water storage capacity [m^3]	4.12...4.42
	Blowdown rate at the reference plant, annual average [m^3/(TP·a)][1]	0.001
	pH value in wash water [-]	ÿ 3
	maximum conductivity in the water reservoir [mS/cm]	ÿ 170
Reference farm for the measurements carried out (broiler farm with pre-catch)		
Broiler husbandry system [System] Approved		Barn-reared, heavy fattening (42 d)
animal places, total house [Number]		32,900
Usable area of the total stable [m^2]		1,600
Maximum stocking density in the stable [kg/		35
m^2] Average live weight pre-catch/finish [kg/animal]		2.2/3.0
installed air requirement per animal [m^3/(h*kg)]		4.5
Summer air rate according to TierSchNutztV, total stable [m^3/h]		252,000
maximum installed exhaust air volume flow, total stable at 20 Pa [m^3/h]		282,776
treated exhaust air volume flow (partial flow, Lavamatic) [m^3/h]		110,000
Max. pressure loss stable plus wastewater treatment plant at 110,000 m^3/h [Pa][2]		260…330
Max. pressure loss wastewater treatment plant at 110,000 m^3/h [Pa][2]		220…280
Number of fans, filtered (Lavamatic) [number]		4
Number of fans, unfiltered [number]		4

Table continued on page 8

feature		Evaluation
Operating behavior		
Technical operational safety	During the test periods, no significant malfunctions were detected, apart from a few failures (power outage, acid dosing failure). The fans are controlled in groups (two each).	ü
durability	No significant wear was observed during the study period.	kB
handling		
Operating instructions	The operating instructions are detailed and clearly structured. Maintenance work and the automatic control system are well described. Numerous safety instructions are provided, and potential hazards are pointed out.	ü
Operation	The system runs fully automatically during normal operation. The plant operator must check the plant control system daily. The plant must be operated continuously.	ü
maintenance	A maintenance contract between the installer/dealer and the system operator is strongly recommended. Maintenance should be performed at least once a year. In addition to the daily inspection of the system control system, monthly and semi-annual visual inspections and cleanings must be performed. These inspections must be documented. The maintenance procedures are clearly described in the operating instructions.	kB
Cleaning the entire system	The system must be cleaned at least after each mast passage. If a pressure loss of 250 Pa is exceeded, the system operator is prompted to clean the system. Every alarm is documented.	kB
Packing change	According to the manufacturer, if the system is operated properly and the necessary maintenance work is carried out regularly, it is not necessary to change the fill material.	kB
Working time required (manufacturer information)		
daily checks	approx. 15 min., plus occasional changing of the strainer basket (25 min.)	kB
weekly checks	approx. 30 minutes	kB
Cleaning the entire system	approx. 2 hours for 2 people	kB
documentation		
Technical documentation	Requirements met	ü
Electronic operating log	Requirements met	ü
Security		
Machinery and plant safety	Confirmed by a recognized occupational safety expert, internal risk assessment	kB
Fire safety	The operator must draw up a fire protection concept for the entire stable as part of the building permit process.	kB
Environmental safety	The wash water must be temporarily stored in a designated storage container in accordance with the German Wastewater Ordinance (AwSV). It is recommended that the wash water be used to meet the plant's needs. The plant operator is responsible for providing evidence of proper recycling. Disposal of other plant components is carried out by approved recycling companies.	kB
Warranty		
Manufacturer's warranty	2-year warranty on all system components not subject to normal wear and tear. Installation is supervised by the manufacturer and maintained according to the maintenance schedule.	kB

* The DLG testing framework provides the following evaluation options in the evaluation schemes:
ü = requirement met, = requ✗ement not met; kB = no rating

1 The blowdown was calculated from the measured nitrogen input.
2 "ARA" is the abbreviation for exhaust air purification system. The filter pressure drop can vary considerably depending on the dust load. The pressure drop of the ARPA corresponds to the pressure drop of the drum plus the pressure drop of the exhaust air duct (stack).

The method

The measurements were carried out at a reference plant in North Rhine-Westphalia.

Due to the fact that dust separation in this cleaning system depends predominantly on the air volume flow, individual dust measurements were carried out under simulated winter conditions before or during the summer measurement for time reasons, whereby the air volume flow was adjusted to the specifications for the period of the dust measurement.

All measurement periods were conducted in accordance with the DLG test framework. Due to structural optimization measures implemented by the manufacturer in the meantime, all previous measurements could not be used for the evaluation, or only partially.

At the manufacturer's request, an explicit review of the odor level optionally offered by the manufacturer was not carried out.

The reference system was a broiler farm with a permitted number of 38,000 birds, although only about 33,000 birds were housed during the test period for animal welfare reasons. The ventilation system of the barn is designed for a total air flow of 252,000 m³/h, for which four exhaust fans were installed in the gable end of the barn ceiling. Of this total air flow, 110,000 m³/h were exhausted via the

Exhaust air purification system was promoted, while the overall ventilation was reduced accordingly (partial flow treatment).

A survey of owners of exhaust air purification systems of the same type could not be conducted during the test period because the tested system in its current form had not yet been put into practical use.

The exhaust air purification system is approved for printing operations.

The measurements took place from August 2023 to August 2024, with individual dust measurements being repeated in 2025.

The following parameters were used to evaluate the exhaust air purification system:

Dust

Sampling was carried out according to VDI Guideline 2066, Part 1 and DIN EN 13284-1.

an isokinetic sampling system according to Paul Gothe with a plane filter head device (Ø 50 mm) was installed.

A round filter made of

Fiberglass with Ø 45 mm selected.

The particulate matter (PM10 and PM2.5) was determined according to VDI Guideline 2066, Part 10, and DIN EN ISO 23210. A Johnas II cascade impactor designed by Paul Gothe with three 50 mm diameter flat filters was used. A glass fiber round filter, this time with a 50 mm diameter, was used as the separation medium. The analysis was performed using gravimetric determination of the dust load.

According to the DLG test framework, a separation efficiency of 70% must not be undercut. This applies to total dust and particulate matter (PM10 fraction). The results of the PM2.5 measurement are presented for informational purposes. The minimum separation efficiency is the lowest separation efficiency resulting from all measurements taken on the measurement days.

Since the dust ingress at all four supply air stacks (raw gas) of the Lavamatic was not uniform and led to significantly fluctuating separation performance of total dust and fine dust, a measurement method was used after consultation with the Technical Committee, which is closely based on the above-mentioned procedure, but whereby all four supply air stacks could be sampled almost simultaneously and evaluated together with the corresponding measurements in the clean gas.

ammonia

Ammonia measurements in the raw and clean gas sections were carried out continuously throughout the entire study period using FTIR spectroscopy in accordance with KTBL publication 401 and DIN EN 15483. The measurements were performed with a measuring cell. To prevent condensation in the gas-carrying PTFE lines, the sample gas lines on the clean gas side were heated along their entire length.

An interferometer rinse was used throughout the measurement period.

The results shown refer to measured values. If less than 0.8 ppm is measured in the clean gas of an exhaust air purification system,

, this value is raised to 0.8 ppm. This is due to the measurement uncertainty of the measuring instrument used. Below this value, a reliable measurement cannot be quantified. Without permanent interferometer purging, the lower measuring range limit is 1.0 ppm.

To demonstrate compliance with the Animal Welfare and Livestock Keeping Ordinance TierSchNutztV (max. 20 ppm ammonia in the animal area), the ammonia concentration at animal level was continuously measured on the measurement days.
recorded.

According to the evaluation criteria of the DLG test framework, the minimum ammonia removal efficiency must be consistently above 70%. The minimum removal efficiency to be recognized is determined from the average removal efficiency of all results minus their standard deviation.

Aerosol discharge

Nitrogen-containing aerosols are expelled from the packings of exhaust air purification systems as ammonium aerosols due to the humidification of the packings and are entrained by the exhaust air flow. Thus, the originally separated nitrogen is inadvertently released back into the environment.

To determine aerosol concentrations during the summer study period, the dust filters from the total dust measurements were tested for ammonium sulfate $(NH_4)_2SO_4$. Conversion to ammonium nitrogen (NH_4-N) was performed using the molar masses of the compounds. The molar mass of ammonium sulfate is 132.1332 g/mol, and the molar mass of the nitrogen contained (2 x N) is 28.0134 g/mol. This corresponds to a proportion of 21.2%. Thus, the ammonium sulfate content was multiplied by a factor of 0.212 to determine the ammonium nitrogen content.

To determine the nitrogen removal with the aerosols, a measurement was carried out during the winter measurement using a plane filter in the clean gas behind the second droplet separator. Two sampling devices were installed, one of which was equipped with a particle filter for aerosol

separation. Sampling was carried out according to VDI 3496-1 (Measurement of gaseous emissions).

According to the DLG test framework, the aerosol discharge must not exceed 0.50 mg nitrogen per standard cubic meter.

Nitrogen balance, N removal

The ammonia removal of the exhaust air purification system was verified by an N-balance taking into account the ammonia loads (in the raw and clean gas) as well as the inorganic nitrogen compounds dissolved in the scrubbing water.

When balancing chemically operated scrubbers, the process water is only assessed with regard to
NH_4-N concentration was investigated, since biological oxidation usually does not occur.

To determine the actual N removal, the removed inorganic N mass is compared with the N load entering from the raw gas side.

A balance of nitrogen flows within the plant is important because

– all relevant nitrogen compounds and their Whereabouts must be proven,

– the nitrogen content of the blowdown water known and its fertilizing value is quantified.

According to the DLG test framework, the N removal must be within the nitrogen balance during the winter
and summer measurements must be at least 70% each.

According to the test framework, the nitrogen recovery rate (N balance) must be at least 80% but not more than 120%.

Consumption values, ambient conditions and system load

The consumption of fresh water, blowdown and electrical energy was determined by recording the corresponding meter readings (electricity meter for exhaust air purification and separately for ventilation).

The acid consumption was determined using a weighing system (force transducer or load cell or scale).

During the measurements, the ambient conditions (outside/inside temperature, outside/inside relative humidity) were recorded.
On the days of the dust and odor concentration measurements, the following parameters were also documented:

– Animal weights (estimated) and animal numbers

– Fresh water and electrical energy consumption (meter readings)

– Air volume flow (manufacturer's measuring fans and separate fan characteristic curve)

– Pressure loss across the system and the pressure loss through the fan

– pH value and conductivity in process water

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

Operational reliability and durability

The operational reliability and durability were assessed. Any malfunctions that occurred in the overall system or in technical components were documented during the inspection period.

Operating instructions, handling and working time requirements, maintenance effort

A detailed functional description of the system with a graphic representation as well as a clear description of the regular maintenance work were examined and assessed from the user's perspective.
In the testing area of handling and working time requirements, it is assessed whether instruction by the manufacturer is required during commissioning and what effort for regularly recurring checks and work at intervals of days, weeks, months, etc. or when malfunctions occur.

When it comes to maintenance work, the service intervals and their lists of obligations are assessed.

documentation

The electronic operating log contains the following
To record and save parameters as half-hourly averages or half-hourly values:

– Pressure loss across the system [Pa]

– Air flow rate [m^3/h]

– Pump running time or operating time of the drum operation (circulation, blowdown) [h]

– Total fresh water consumption of the system [m^3], cumulative

– Blowdown volume [m^3], cumulative

– Raw and clean gas temperature [°C]

– pH value [–] and electrical conductivity [mS/cm], each as half-hour averages

– Electricity consumption of the exhaust air purification system [kWh], cumulative

In broiler farms, the
The running time of all emergency ventilators used must be documented.
ren.

Furthermore, maintenance and repair times as well as calibrations of the pH probe must be recorded.
Evidence of the consumption of chemical operating materials (acid, antifoam agents) as additives must be provided.

These data serve to demonstrate proper operation of the exhaust air purification system and were verified on the reference system.

Environmental safety

The environmental safety audit included an assessment of any operating materials required for plant operation, such as acids and alkalis.
Furthermore, the recycling of generated operational waste, such as the sludge-removed process water, as well as the dismantling and disposal of plant components, are being investigated and assessed. Furthermore, the areas of responsibility for these aspects were examined.

Security aspects

To assess plant safety, the plant's compliance with the currently applicable regulations in the areas of fire and plant safety was checked.

The test results in detail

The test was conducted on a reference system with an installed cleaning capacity of 110,000 m³/h per exhaust air treatment system (4 supply air fans). Systems operating with fewer fans but otherwise identical in design and function can also be considered certified.

All necessary measurements were carried out during the test, but the manufacturer decided in the meantime to optimize the process technology and thus also improve the separation values.

From the first three measurement periods (1x summer, 2x winter) the emission

measured values and consumption figures are used only to a limited extent or not at all. Furthermore, measurements were carried out after the procedural change to demonstrate reliable separation. This also applies to subsequent dust measurements (total/ particulate matter PM10) under winter conditions, which did not lead to satisfactory results due to a lack of technical optimization work in previous measurement periods. A dust particle must strike a water droplet with sufficient momentum, be bound by it, and then mechanically separated. Accordingly,

Table 3:

Measurement results for emission reduction (total and fine dust) at the exhaust air purification system

	Measurement under					
	Summer conditions		**Winter conditions**			
Date	**19.09.24**	**23.09.24**	**07.08.24**	**31.03.25**	**07.04.25**	**08.04.25**
Mast course	**Day 36**	**Day 40**	**Day 41**	**Day 32**	**Day 39**	**Day 40**
Environmental and boundary conditions[1]						
Relative outdoor humidity [%RH]	63	70	70	68	40	48
Ambient temperature [°C]	18.2	22.1	22.1	9.9	11.4	11.5
Raw gas/clean gas humidity [%RH]	83/97	74/96	79/98	72/99	57/98	76/99
Raw gas/clean gas temperature [°C]	21.3/20.0	24.3/20.0	25.2/22.4	24.3/18.3	22.4/15.8	20.6/17.8
Number of animals in the stable [pcs]	21,897	21,883	20,761	31,548	21,007	20,996
Average animal weight [kg]	2.23	2.62	2.9	2.00	2.70	2.80
Air volume flow [m³/h]	95,000	95,000	36,900	39,500	39,500	39,500
Pressure loss ARA [Pa]	278	243	38	– –[2]	– –[2]	– –[2]
Total dust (standardized)[2]						
Raw gas [mg/m³]	2.08	2.62	--	4.3	6.33	5.61
Clean gas [mg/m³]	0.39	0.33	--	0.47	0.47	0.38
average separation efficiency [%]	81.1	87.3	--	88.9	92.6	93.3
Minimum separation efficiency [%]	81.1		88.9			
Fine dust PM10/PM2.5 (standardized)[3]						
Raw gas [mg/m³]	1.42/0.85	1.39/0.86	1.58/0.62	1.76/0.54	2.41/1.00	2.44/0.80
Clean gas [mg/m³]	0.37/0.15	0.39/0.16	0.32/0.10	0.46/0.09	0.30/0.03	0.31/0.01
Average separation efficiency PM10/PM2.5 [%]	74.2/82.1	72.3/81.4	79.4/84.0	74.0/84.2	87.6/96.9	87.2/98.2
Minimum separation efficiency PM10/PM2.5 [%]	72.3/81.4		74.0/84.0			

1 The data were collected at the time of dust measurement.
2 The measured values were implausible or could not be collected for technical reasons.
3 Some of the values shown are rounded to one decimal place. However, the separation values were calculated using the calculated using unrounded values.

In this case, the volume flow and the speed of the drum are decisive for dust separation. Other influences (e.g., humidity/ temperature) play a subordinate role in dust separation. For this reason, dust measurements

at low volume flows (winter measurement) can also be carried out in a warmer season.

For this purpose, the volume flow was briefly reduced to winter air rates (approximately 30%) during the dust measurements. With this tactic, all required dust measurements could be

Measurements were carried out within a few days of the official measurement periods. Ammonia removal was checked parallel to each dust measurement, and all required boundary parameters as well as animal-specific data were always collected, so this measurement planning was permitted here.

Dust

The exhaust air purification system used was able to meet the requirements of the DLG test framework.
Table 3 shows the measurement data of the winter and

Summer measurement shown.

In winter, a total of eight total dust and four fine dust measurements (PM10 and PM2.5) were carried out.
In the summer, four total dust measurements were

and four particulate matter measurements were carried out. All values were above 70%, but in this report

only the values according to the procedural

Change presented and evaluated.

For total dust, a minimum separation efficiency of 88.9% (winter) and 81.1% (summer) was measured.
In addition, at least 74.0% of PM10 particulate matter was removed in winter and 72.3% in summer.

Experience has shown that the washing process can lead to the formation of droplets in the size range of 2.5 to 10 µm, which results in increased detection of the PM10 particle fraction when measuring dust with the cascade impactor . The PM2.5 particle fraction is less affected by this effect. Therefore, a higher separation efficiency is usually calculated for this particle fraction than for the PM10 fraction.

ammonia

Ammonia removal that at least meets the requirements can only be ensured if the process water is automatically elutriated at a maximum conductivity of 170 mS/cm and the pH value in the water is regulated at ÿ 3.0.

Continuous monitoring of ammonia concentrations at animal level revealed hardly any abnormalities. A few exceedances of over 20 ppm are attributable to removal and manure removal processes, as well as pre-capture, and are therefore part of normal operation.

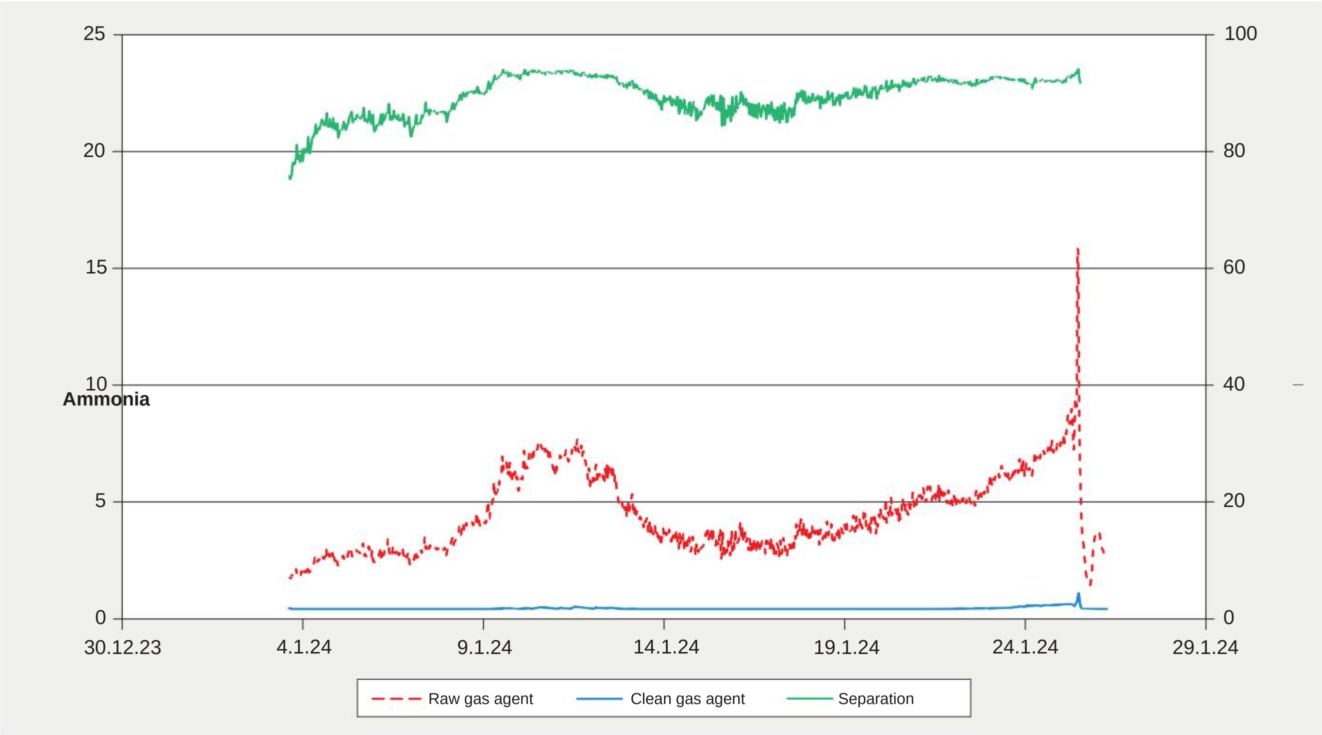

Image 3:

Separation efficiency and course of ammonia concentration in raw and clean gas (winter measurement)

Table 4:

Results of the aerosol discharge at the Lavamatic exhaust air purification system

	Summer measurement 2	
Date	19.09.24	19.09.24
Total air volume flow [m³/h]	95,000	95,000
Ammonium sulfate [mg/filter]	0.08	< 0.07[1]
NH3-N aerosol discharge [mg/mn³]	0.03	< 0.02[1]

1 The analyses were below the detection limit.

Table 5:

Measurement results (N-balance and wash water composition) of the exhaust air purification system

		Winter measurement 1	Winter measurement 2	Summer measurement 2
Measurement period		**January 3 to January 24, 2024**	**February 20 to March 13, 2024**	**September 5 to September 23, 2024**
Animal species				
Total number of animals	[Piece]	32,400	32,400	32,900
Gas side				
NH3-N raw gas input	[kg]	87.92	96.77	50.12
other gaseous N compounds [kg]		0	0	0
NH3-N clean gas discharge	[kg]	6.62	8.65	8.91
other gaseous N compounds [kg]		0	0	0
difference	[kg]	81.3	88.1	41.2
NH3-N separation efficiency	[%]	92.5	91.1	82.2
Waterside				
pH value[1]	[-]	2.3…3.2	2.6…3.1	2.9…3.2[2]
Conductivity[1]	[mS/cm]	14…94	10…88	0…39
Ammonium-N	[g/l]	4.9…21.2	1.2…19.0	0.2…8.3
Nitrate-N	[mg/l]	29.4…45.0	0.1…21.8	na[3]
Nitrite-N	[mg/l]	< 0.03	< 0.03	na[3]
filterable substances	[g/l]	7.2…11.4	1.6…12.2	na[3]
N-aerosol discharge	[kg]	--	--	--
N-circulating water discharge	[kg]	80.96	89.42	39.9
N-sludge removal	[kg]	0	0	0
Total nitrogen leaching in water	[kg]	80.96	89.42	39.9
Recovery rate N	[%]	99.6	101.3	97.4
N removal[4]	[%]	92.1	92.4	79.6

1 The data were taken from the electronic operating logbook.
2 On some days, there was a significant pH increase due to an empty acid container or air in the circulation line. Since these events do not reflect normal operation, the affected values are not shown here.
3 Measurement data were not collected.
4 The N removal was calculated without taking aerosol discharge into account.

To reduce the influence of increased ammonia concentrations To exclude concentrations of more than 20 ppm in the raw gas from the calculation of the separation efficiency, all measurement pairs in which more than 20 ppm were measured in the raw gas were eliminated. Ultimately, 1,957 measurement pairs from the winter and 605 measurement pairs from the summer measurement were available for evaluation. Since process optimization work was carried out on the plant after the first summer measurement, which could have an impact on the separation efficiency, these data cannot be used for the evaluation.

A minimum separation efficiency of 83.0% was measured in winter. In summer, at least 73.8% was consistently achieved.

Figure 3 shows the ammonia concentrations at Example of winter measurement shown graphically. All measured values were corrected, ie values below 0.8 ppm were increased to 0.8 ppm (interferometer flushing).

At least 70% of ammonia was removed on all measurement days. Effective ammonia removal in broiler farms and under proper operation is thus ensured under the described operating conditions.

Aerosol discharge

The results of the aerosol measurements are summarized in Table 4. Six measurements were taken in winter and four in summer, but only two measurements from the last series could be presented and evaluated. In each case, measurements were taken downstream of the drum washer.

Both before and after the process engineering Optimization significantly undercut the DLG test limit of 0.5 mg N/m³. This ensures good aerosol retention.

Nitrogen balance/N removal

The results of the nitrogen balance and N removal are given in Table 5.

The winter measurements resulted in a nitrogen recovery rate of 99.6%, 101.3% in winter, and 97.4% in summer. This result is very good in terms of measurement accuracy.

Nitrogen removal rates of 92.1% and 92.4% were achieved in winter, and 79.6% in summer, reflecting stable and reliable operation overall. Due to the described optimization measures at the plant, the nitrogen balance from the first summer measurement cannot be used for evaluation.

Consumption values, ambient conditions and system load

To represent all consumption figures, daily averages were recorded and included in the test report. Since only a partial flow was treated at the reference system, a representative representation is only possible to a limited extent. Since almost the entire exhaust air flow at the reference system was conveyed through the exhaust air purification system during the test period, the determined consumption values can be related to the animals housed (an average of 32,500 animals). However, these consumption figures only apply to barns operated with exactly the same partial flow filtration.

Since a larger exhaust air purification system must be maintained for complete exhaust air treatment of 32,500 animals, higher media consumption is expected with full filtration.

The consumption values given in the test report (Table 1) per measurement period (winter/summer) are standardized to annual consumption values (operation 365 days a year). This allows a direct comparison with comparable systems in other DLG test reports. In order to additionally

In order to be able to give a more practical value, the value was based on approximately 240 days a year. This includes service times (assuming 7.5 cycles per year) and a scrubber start starting on the 10th day of fattening. When specifying the energy consumption of the ventilation, only the service time was taken into account, since the ventilation is already active from the first day of fattening.

The following only deals with the average annual consumption.

The first summer measurement cannot be used to assess consumption figures (drum speed only 2 rpm). However, the measurement data from the immediately following winter measurement (drum speed 3 rpm) can be used with limitations, as the adjustment of the exhaust air stacks (4 stacks in the clean gas instead of the previous 2, use of more powerful fans) has not yet been completed, but this is expected to have only a limited impact on consumption figures.

Water consumption

Water consumption depends on the Sludge removal rate and evaporation. The more sludge is removed and the more evaporates, the more fresh water must be added to keep the process water quantity in the system constant.

The blowdown rate depends on the nitrogen entry via the exhaust air flow and the limit value for the maximum conductivity in the process water. This was 170 mS/cm during the measurement period. Since this limit was never reached during the measurement, elutriation was not possible. Therefore, a theoretical value was calculated from the nitrogen input. This value is 0.001 m³/(TP·a).

The total freshwater consumption was 2.2 m³/d, which corresponds to 0.03 m³/(TP·a) with 365 days of scrubber operation per year or 0.02 m³/(TP·a) with 240 days per year. The freshwater was added directly to the water reservoir in each case.

Consumption of electrical energy

Energy-intensive circulation pumps are not required in this process, since in this case the cleaning of the exhaust air and the humidification of the packings are carried out by immersion in the washing liquid. The circulation pump (Figure 2) and the drum rotation generate comparatively low energy consumption. Thus, the power consumption of the exhaust air purification system is significantly lower than that of systems with vertical or horizontal filter walls. The exhaust air purification system consumed 17.9 kWh per day. Converted to an annualized rate, this would be 0.21 kWh/(TP·a) and 0.14 kWh/(TP·a), respectively.

In the stable area, the fans are the largest consumers. In the reference operation, the exhaust air Four pressure-stable exhaust fans were used in the cleaning system. The fans were controlled with 0-10 V to adjust their speed to the exhaust air flow rate to be conveyed.

The maximum pressure losses determined at the Lavamatic were between 220 and 280 Pa for the washing drum, including the exhaust air duct. The exhaust air purification system plus the stable system produced a Total pressure loss of 260 to 330 Pa. The fluctuation The differences were caused by the varying degrees of soiling in the washing drum.

For optimal ventilation design, the fans must be designed for at least 300 Pa if the required air volume is to be conveyed.

On average, a total of 105.3 kWh/day was consumed for ventilation. It should be noted that significantly more energy was consumed in summer. Based on animal space and year, this would be an electrical energy consumption of 1.24 and 1.07 kWh, respectively.

The electrical energy consumption of the exhaust air purification system is significantly lower than that of comparable systems due to the lack of circulation pumps. The higher power consumption of the ventilation system is primarily due to the higher backpressure of the washing drum.

The values given refer to partial-flow filtration. Since the test was conducted on a reference system with partial-flow treatment, no reliable values can be given for full exhaust air treatment. The fans of the exhaust air purification system consistently operated in an unfavorable range of the characteristic curve during the test period.

Other consumption values

Safe system operation with the efficiency levels shown is only possible with a properly operated pH value control at 3.0 and a blowdown at a maximum of 170 mS/cm.

Therefore, an automatic acid dosing system and conductivity measurement must be installed and operated at the plant. Sulfuric acid with a concentration of 96% was used to lower the pH at the reference plant.

The annual average acid consumption was 8.4 kg/day was measured. Based on animal place and year, 0.10 kg and 0.06 kg of acid were consumed, respectively.

The manufacturer offers the addition of an antifoam agent via a dosing device as standard. No antifoam consumption was observed during the DLG test.

No further additives were added during the test.

Operational reliability and durability

During the inspection period, hardly any significant malfunctions were detected in the system's technology. No significant damage or signs of wear were observed on the entire exhaust air purification system during the inspection.

The corrosion protection of the individual system components appears to be

As observed, the system is sufficiently durable. The complete system is made almost entirely of plastic.

The durability could only be determined over the duration of the The test (measurement period) was observed. A survey of operators of similar systems was not conducted because the system being tested was unique in this form.

Operating instructions, handling and Working time requirements, maintenance effort

The operating manual is sufficiently well-written and explains the system's functionality in a simple and understandable manner. In conjunction with the documentation, the operator learns which tasks must be performed on the system on a daily, weekly, and annual basis. To make operation easier to understand, the operating manual includes photos of the control display.

To operate the system, it is necessary to undergo training by the manufacturer and to familiarize yourself with the operating instructions.

After commissioning and a sufficient run-in phase, the system is easy to operate, as the exhaust air purification system runs fully automatically during normal operation. Only a daily check of the operating data and a weekly check of the entire exhaust air purification system, including the drum operation and the occasional cleaning of the screen basket, are required.

If the control system issues error messages, the operating instructions contain instructions for checking the respective system components.
To simplify handling and reduce labor requirements, we recommend concluding a maintenance contract with the dealer. The manufacturer provides training to all listed dealers.

Table 6:

Fulfillment of the requirements for the electronic operating log of the Lavamatic plant

	fully fulfilled	not fulfilled	Remarks
Pressure loss across the Exhaust air purification system	X		is recorded and stored using an electronic differential pressure cell
Air flow rate exhaust air purification system	X		is measured via measuring fans in the supply air chimney
Air flow emergency fan	X		A measuring signal is picked up and stored via the switching contacts of the emergency ventilator
Drum operation	X		is recorded and stored via the drum motor sensor (0…100%)
Fresh water consumption	X		the total fresh water consumption is recorded using a water meter
Amount of elutriated water	X		is recorded and stored via a flow meter
Raw and clean gas temperature	X		the raw and clean gas temperature is measured and recorded using a thermal sensor
Maintenance and Repair times	X		can be recorded and saved by the operator in the manual operating log
pH and conductivity	X		are recorded and stored
Calibration of the pH sensors	X		can be recorded and saved by the operator in the manual operating log
Proof of consumption of additives (acid, Antifoam)	X		Acid consumption is recorded and stored via the strokes of the acid pump, and the consumption of antifoam agent can be verified via delivery notes
electrical power consumption	X		The power consumption of the washer is recorded and stored via a suitable electricity meter

The exhaust air purification system must be cleaned (basic cleaning) after each mast passage. If possible, no basic cleaning should be carried out during the mast passage. Due to the achievement of the conductivity

in the wash water of 170 mS/cm, however, a Blowdown is performed (automatically). When a pressure loss of 250 Pa is reached, the operator is prompted to perform a manual blowdown. An alarm message is generated each time this occurs, which is also saved in the EBTB.

documentation

The electronic operating logbook enables regular and compliant recording of the data required for safe plant operation. These data must be saved as half-hourly averages (pH and conductivity) or half-hourly values. Recording is automatic, and the data must be stored for five years. This data can be read out by the operator, the manufacturer, and even authorities via a USB port and converted into a common spreadsheet format.

A detailed presentation of the recorded data can be found in Table 6.

If the barn ventilation and exhaust air purification system are installed by different manufacturers, the ventilation data is recorded as a characteristic curve by the exhaust air purification manufacturer and also integrated into the exhaust air purification control system for regulation. The maximum fan power is set to 100% in the control system. However, adjustment within a wider performance range is not possible. Since the air flow rate must be specified in absolute m³/h according to the test framework and the requirements of the TA Luft (Chapter 5.4.7.1), a characteristic curve for the entire ventilation system (barn plus exhaust air purification) must be recorded before commissioning and integrated into the electronic operating system.

diary. The characteristic curve should consist of at least five different support points between an air rate of 0 and 100%.

According to the current TA Luft (Technical Instructions on Air Quality Control), the density in the wash water of chemically operated plants must also be continuously measured and stored in parallel with the conductivity, since conductivity measurements become too inaccurate above approximately 250 mS/cm. In a resolution passed by the Technical Committee, it was determined that the density determination for the present

The following procedure is not necessary, since only up to a conductivity of maximum 170 mS/cm can be is centered.

Environmental safety

The main ammonia removal occurs purely chemically with the formation of ammonium sulfate. Ammonium sulfate is a water-polluting substance and is assigned to water hazard class WGK 1 (slightly water-polluting).

The storage space must comply with the current Fertilizer Ordinance, which stipulates the storage period for liquid manure. The inlet line to the blowdown tank and the storage tank itself must be suitable for the blowdown water.

In this case, the country-specific administrative regulations for water-polluting substances (ammonium sulfate) must be observed. Immediately before application to agricultural land, the eluted water can be mixed with liquid manure outside the barn. Agricultural utilization based on plant needs, taking into account the nitrogen and sulfur content, is technically advisable.

Acid is required for safe plant operation. Handling must be explained in an operating manual provided by the manufacturer and carried out in accordance with the EC safety data sheets for 96% sulfuric acid. This is the responsibility of the plant operator. All appropriate safety equipment (eyewash station, full-body shower, protective clothing) must be provided. An acid reservoir in the form of an IBC container is recommended.

According to the manufacturer, the dismantling and disposal of other system components can be carried out by approved recycling companies.

Security aspects

Fire safety must be demonstrated by means of an appropriate fire protection concept, which must be drawn up by the operator in conjunction with the manufacturer and attached to the building application.

The machine and system safety of the described exhaust air scrubber was assessed by Klaus Ahlendorf GmbH during the initial inspection in 2024. There are no occupational safety-related objections to the use of the system.

no concerns.

Conclusion

The “Lavamatic” exhaust air purification system from GrainProteinTech Climate Control & Air Treatment Germany GmbH is suitable for reducing emissions of dust and ammonia (including nitrogen removal) from the exhaust air stream of litter-filled broiler systems.

The single-stage process consists of a wet-chemical exhaust air scrubber. The system operates on the pressure principle. For reliable system operation, the filter volume load of the scrubbing stage must not exceed 8,700 $m^3/(m^3\ h)$. The pH value in the water reservoir must be set to ÿ 3.0, and the conductivity must not exceed 170 mS/cm.

If the described process parameters are adhered to, the minimum requirements of the DLG test framework for dust and ammonia reduction are met and in some cases exceeded.

The approved minimum removal efficiencies for total dust are 88.9% in winter and 81.1% in summer. PM10 particulate matter is reduced by 74.0% in winter and 72.3% in summer. The minimum removal efficiency for ammonia is 83.0% in winter and 73.8% in summer. Nitrogen is removed by 92.2% in winter and 75.6% in summer.

Further information

Examination conduct

DLG TestService GmbH, Groß-Umstadt location

The tests are carried out on behalf of the DLG eV.

Laboratory and emission measurements

LUFA North-West

Jägerstraße 23-27, 26121 Oldenburg

DLG test framework

DLG overall test
“Exhaust air purification systems for animal husbandry facilities”
(As of April 2022)

Field of expertise

Operating resources

Department Head

Dr. Michael Eise

Test engineer(s)

Dipl.-Ing. (FH) Tommy Pfeifer*

Technical Committee (Examination Committee)

Friedrich Arends, LWK Lower Saxony
Christian Dohrmann, farmer
Bernhard Feller, LWK North Rhine-Westphalia
Doris Focken, Cloppenburg district
Ewald Grimm, KTBL Darmstadt
Dr. Jochen Hahne, TI Braunschweig
Andreas Schlichting, TÜV Nord Hamburg
Thomas Üffing, farmer

* Rapporteur

DLG. Open network and expert voice.

The DLG (German Agricultural Society), founded in 1885 by Max Eyth, is a professional organization for the agricultural and food industry. Its guiding principle is the transfer of knowledge, quality, and technology to promote progress. The DLG acts as an open network and professional voice in the agricultural and food industry.

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