VERA TEST PROTOCOL

for
Livestock Housing and Management Systems

Version 3:2018-09

VERA

Verification of Environmental Technologies for Agricultural Production

Foreword

To meet the environmental challenges in livestock production, new technologies are being developed within EU member states and elsewhere. These so-called environmental technologies are designed to potentially enhance the eco-efficiency of livestock production by reducing material inputs, emissions of pollutants, and energy consumption, in addition to recovering valuable by-products and minimising waste disposal problems. Environmental technologies in agriculture can be introduced in different stages of the production chain, e.g. techniques applied in animal houses or techniques for manure storage, processing, or land application.

However, central stakeholders, such as farmers and authorities, only have limited information about the performance of these technologies, which hampers their diffusion in the agricultural sector. The Danish Ministry of Environment, the Dutch Ministry of Infrastructure and Environment, the German Federal Ministry of Food and Agriculture and the German Federal Environment Agency, in cooperation with international technical experts, have therefore begun the development of common test protocols for the testing and verification of such environmental technologies for agricultural production. The VERA test protocols are designed to investigate the environmental performance and operational stability of a technology, thus providing reliable and comparable information about the performance of technologies to farmers, authorities, and other stakeholders.

This initiative is organised by VERA - Verification of Environmental Technologies for Agricultural Production. The VERA cooperation was established in 2008 to promote an international market for environmental technologies for agricultural production. The overall purpose of VERA is to fill the information gap for main stakeholders by offering independent verification of the environmental performance and operational stability of environmental technologies determined by applying specific VERA test protocols.

The first version of the protocol for Livestock Housing and Management Systems was finalised in December 2009, version 2 in June 2011. The present version 3 was published in September 2018.

Questions and comments on the VERA test protocols should be sent to

International VERA Secretariat
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Amendments

This edition of the VERA test protocol has been thoroughly revised to reflect the latest state-of-the-art, and differs from the earlier version 2:2011 as follows:

a. The former versions focused primarily on measurements in mechanically ventilated buildings, like those commonly found in pig and poultry production due to the lack of commonly accepted methods for **naturally ventilated buildings**. With dairy cow houses becoming a more important target for emission considerations, new methods were validated and experience on an international basis was gained. These were now commonly agreed and have been introduced in this document in collaboration with scientific experts from additional countries to the current three member countries of Denmark, Germany and the Netherlands.

b. The **use of tracer gases**, both artificial ones and metabolically produced, were introduced in this new version including detailed instructions and recommendations on how to use tracer gases for emission measurements in an animal house. The Annex of this document provides practical examples.

c. The calculation of the emissions measured with tracer gases requires detailed equations including making some assumptions. In order to maintain a high comparability of results and to make the evaluation during the VERA verification easier, a separate **Excel spread sheet** was developed, which will be shared on the VERA website along with this VERA test protocol.

d. This VERA test protocol allows the testing of many different technology types in many different test environments, such as various animal productions and housing types. It was therefore considered necessary to provide a clearer and more **elaborate description** when choosing the right test locations and test design.

e. The requirements of 'at least six measurement days' were sometimes misinterpreted in practice. Depending on the test setup, more than six 24-hour periods may be necessary to adequately quantify the emissions and/or reduction values. This was phrased more clearly.

f. Instead of listing suitable measurement methods for the test parameters, this new version of the VERA test protocol introduced a **'standard reference method'**, according to EN 14793. A standard reference system was now defined for the key measurement parameters. This method is validated and has proven its suitability for that use and is as such commonly recognized. The equivalence of any other measurement method must be demonstrated, e.g. as described in EN 14793.

g. With the simultaneous revision of other VERA test protocols, the general format and structure of the documents have been harmonised by means of a new 'high level structure' for VERA test protocols. This should help the user to navigate the documents, in addition to being closer to the format of an international standard.

Previous editions

VERA Test Protocol for Housing Systems Version 2:2011-08

VERA Test Protocol for Housing Systems Version 1:2009-09

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1. Introduction

The objective of this test protocol is to specify the test procedures for the environmental efficiency of technologies for livestock housing and management systems. This includes definitions, specific requirements and conditions for testing, measurement and sampling methods, processing and interpretation of measurement results, and reporting specifications. More general requirements for the parties involved in the test and the individual process steps for testing and verification are laid down in the 'General VERA Guidelines' which were approved by the International VERA Board.

This document was drawn up by nominated international experts of the 'International VERA expert group' (IVC) for livestock housing and management systems.

Since the 1990s, a number of systems have been developed with the aim of lowering ammonia emissions from livestock houses. These systems are generally based on standard housing systems with modifications in pen design and manure storage to reduce emitting surfaces, or manure management systems for quick removal or quick drying. The BREF guide for intensive livestock operations gives an overview of available systems for pigs and poultry. Besides ammonia, odour and dust emissions have become an important issue in regions with high animal densities. This had led to the development and introduction of air cleaning technologies in Northern Europe. However, in many cases, implementation of new livestock housing and management systems may also be an attractive option for farmers to reduce ammonia, odour and dust emissions – not only for meeting the environmental goals, but also for improving the indoor housing climate leading to higher animal welfare levels and better working conditions at the same time.

The aim of the VERA verification statements is that its information can be optimally used by different stakeholders in the member states. This means that the test protocol should provide a broad array of reliable information that can be analysed and summarised during the verification in such a way that it can be directly or indirectly used as widely as possible by the different national users.

However, due to reasons of costs and time, test protocols have restrictions on the number of parameters to be evaluated, and the applicable scientific methods and standards are limited. The starting point in the design of this test protocol was therefore to create an optimal balance between reliable information that meets the demands of the different users, and costs in terms of time and expenses for carrying out tests.

2. Scope

This protocol specifies the information needed for testing and verifying the environmental performance and operational stability of 'livestock housing and management systems'.

2.1. Definition of 'livestock housing and management systems'

A livestock housing and management system is defined in this protocol as a unit with the primary function of providing housing for a specified animal category. Its specific design, equipment and/or management practice determines its environmental performance. In principle, all elements in an animal house that affect the external environment may be included in the definition of such a system.

Systems that reduce emissions can be defined in such a way that they include a specific description of one of the following factors:

- Housing design, including design of pen, manure storage and removal system
- Bedding material and other loose materials
- Additional indoor technical installations and management
- Treatment of indoor air/climate

- Manure treatment, including additives and management
- Feed composition, including additives and management
- General management

2.2. Targeted results and information

The information specified includes:

- A comprehensive system description, including user manual
- Technical performance of the system based on data collected during the test period
- Measurement methods including requirements, sampling strategy, data collection and handling, calculation methods, reporting
- Evaluation parameters to assess the environmental performance and operational stability of the system tested.

This protocol describes the requirements for verifying the effects on the fate of gaseous emissions from animal housing of the physical design and management of a livestock housing system, and/or application of feed and manure additives during a defined testing period.

In practice, the major environmental effect of an animal housing system is represented by emissions of ammonia, odour and particulate matter. Livestock housing and management systems can therefore be characterised by their ability to reduce one or more of these emissions. Thus, this test protocol outlines the methods and demands for testing a system for its effect on those aspects as its primary parameters. A test can be designed to test the primary target parameter of the technology, e.g. an ammonia reducing technology, thereby omitting testing of the other primary parameters. However, this is only possible if it can be ensured that the technology in all probability does not have any negative effect on the non-tested parameters.

During the test period, the operational stability and deviations from normal operational functioning must be observed, recorded, and reported in the test report. Animal productivity, animal health and welfare, working environment and the external environment observed during the testing period will all be addressed in the evaluation report.

2.3. Use of results for verification

After a test has been completed, verification of the environmental efficiency based on the test results can be carried out in accordance with this protocol and the General VERA Guidelines.

VERA does not endorse, certify, or approve technologies!

VERA verifications are based on an evaluation of the technology performance under specific, predetermined criteria and the appropriate quality assurance procedures. VERA makes no expressed or implied warranties as to the performance of the technology and does not certify that a technology will always operate as verified. The end user is solely responsible for complying with any and all applicable federal, state, and local requirements. Further, the end user must be aware that the countries involved in VERA have different legal requirements, which will influence the status and use of this verification statement in each country.

3. Normative references

The referenced standards in the following text and in the bibliography are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

4. List of abbreviations

a	Annus (Latin for year)
A	Animal
AP	Animal place
C	Carbon
CIGR	International Commission of Agricultural and Biosystems Engineering
CH_4	Methane
CO_2	Carbon dioxide
CF	Crude fibre
CP	Crude protein
DM	Dry matter
FPCM	Fat and protein-corrected milk
GC-ECD	Gas chromatography - electron-capture detector
GC-FID	Gas chromatography – flame-ionisation detector
GC-TCD	Gas chromatography – thermoconductivity detector
GHG	Greenhouse gases
IVB	International VERA Board
IVC	International VERA Committee
K	Potassium
LU	Livestock unit
ME	Metabolic energy
N	Nitrogen
NH_3	Ammonia
N_2O	Nitrous oxide
NOx	Refers to NO (nitric oxide) and NO_2 (nitrogen dioxide)
OU_E	European odour units
P	Phosphorus
PM	Particulate matter
ppm	Parts per million
TAN	Total ammoniacal nitrogen
TDL	Tunable diode laser
VERA	Verification of Environmental Technologies for Agricultural Production

5. Terms and definitions

Ammonia (NH_3)
A gas derived from urea excreted by livestock (in poultry, NH_3 is excreted from uric acid) and implicated in acidification and nitrogen enrichment of sensitive ecosystems.

Animal category
The type of animal according to their species (pigs, cattle, chicken, ducks, turkeys, etc.), sex, age and scope of production (breeding, rearing, growing and finishing for meat, milk or egg production).

Animal housing system
See 'Livestock housing system'.

Background concentration
Concentration of aerial pollutants in the incoming air.

Compartment
Separate part of an animal house with its own ventilation and manure system.

Downtime
Period of time when the system tested is not operating, e.g. as a result of malfunctions.

Dust
See 'particulate (or particular) matter'.

Emission value
Emission level of a given pollutant from an animal house into the atmosphere. It can be expressed as the integrated mass emitted per time interval and animal produced (e.g. kg $year^{-1}$ $animal^{-1}$), livestock unit (e.g. OU_E s^{-1} LU^{-1}) or per m² floor (e.g. kg $year^{-1}$ m^{-2}). It may also be expressed as a percentage (e.g. % total ammoniacal nitrogen or total nitrogen).

Feed composition
Description of the individual ingredients and their nutritional value that constitute a feed formula/ diet.

Feeding technique
Description of the technical installations for mixing, transportation and dispensing of the feed to the animals. The feed can be applied in solid or liquid form.

Floor design
Floor type, e.g. solid (concrete) floor including the use of bedding material, or slatted floor. The slats can be made of metal, concrete or plastic.

Greenhouse gases (GHG)
Gases that contribute to the 'greenhouse effect' and global warming. In this context, these are primarily methane (CH_4) and nitrous oxide (N_2O).

Heating system
Installation for production, transportation and distribution of heat in the housing system.

Incoming air
Preferred instead of the term ‘background’ (air) to distinguish the effects of nearby emission sources from a ‘clean’ background.

Livestock housing system
A unit with the primary function of providing housing for a specified animal category, and with specific designs, equipment and management which determines its environmental performance. It includes the way a certain animal category is stocked (e.g. floor and pen design); the manure storage and management system; the ventilation system installed to control indoor climate in the building; and the type and regime used to provide feed and water to the animals. It can be divided into separate compartments or different functional areas.

Livestock unit (LU)
A unit used to compare or aggregate numbers of animals of different species or categories. Often one LU = 500 kg live weight of an animal category. Other equivalences are defined on the feed requirements (or sometimes nutrient excretion).

Manure system
Collection and removal of slurry or manure out of the housing system, e.g. by gutters, channels, scrapers.

Norm emission factor
Description of an emission factor for a standard housing system, which is used as a reference standard factor in the individual countries.

Odour
Pleasant or unpleasant smell caused by different odorants with different chemical, physical and biological properties. The odour concentration is given in European Odour Units per cubic metre of air ($OU_E\ m^{-3}$) and the concentration is measured by olfactometric analyses in accordance with the European CEN standard EN 13725.

Particulate matter (PM)
Often also called dust.
Fine solid or liquid particles suspended in a gaseous medium.
Different fractions are specified by the aerodynamic diameter as well as by the sampling and evaluation method as defined in the respective standards, e.g.:

Term	Definition	Standard
PM10	Particulate matter that passes through a size-selective inlet with a 50% efficiency cut-off at 10 µm aerodynamic diameter.	EN 12341
PM2.5	Particulate matter that passes through a size-selective inlet with a 50% efficiency cut-off at 2.5 µm aerodynamic diameter.	EN 14907
Inhalable dust (ID)	Total airborne, finely divided solid and liquid particles which are inhaled through the nose and mouth, generally with an aerodynamic diameter of approximately PM100.	ISO 7708 EN 481
Total dust (TD)	Airborne particles that can be collected using 37-mm filter cassettes.	NIOSH 0500
Total Suspended Particles (TSP)	Archaic term used by the US EPA before PM10 was introduced. Defined as particles up to 25-50 µm, depending on wind speed and direction. Relates roughly to a PM35.	40 CFT 50, appendix B

Pen
A small enclosure for livestock, within a house or outdoors.

Pen design
The structuring of a pen with separate areas for lying, feeding and defecation. Single-area pens are not structured.

Standard housing system
The standard housing system describes the most common animal housing systems in a particular country.

Uptime of the system
The period of time when the system being tested is in operation.

Ventilation system
System to provide fresh air and to remove gaseous products, heat and moisture to ensure a suitable climate in a livestock building. Ventilation can be designed either as a forced or a natural ventilation system.

Ventilation rate
The ventilation rate gives the volume flow of air (e.g. $m^3 h^{-1}$) through an animal house. It can be given for the entire animal house or compartment, or per animal (place).

Verification
Confirmation that a test has been performed according to a standard.

6. System description

The manufacturer/applicant is responsible for providing a precise and full description of the system or technology before initiation of a VERA test. This information should be provided as essential data required for test institute, users of the system, verification authorities, etc. To some extent it also forms part of the test plan and the final test report. The system description must include all relevant and essential information that is needed to:

- Organise and design the test;
- Enable the farmer to operate, maintain and monitor the system properly;
- monitor the system online, including the key parameters needed for the determination of uptime/downtime of the system (only where relevant, e.g. not for floors);
- Allow the verification authorities to check the system after a test has been carried out;
- Provide detailed insights into working mechanisms of the system (for additives: description of chemical or biological reactions and mass balances for the key target compounds (e.g. ammoniacal nitrogen or hydrogen sulphide)).

The description must include detailed information on the housing system in which the technique or system is applied. The following aspects must be taken into consideration:

- Animal category (species, breed, weight range, herd size, total number, space provided per animal);
- Management of the livestock and pen design (description of pen design, a drawing would be helpful);
- Construction and dimensions of the building including the compartments below the floor (materials, insulation, compartments, capacity, length, width and height);
- Ventilation system and its design (ventilation types, sizes and numbers of air inlets and outlets, capacity, set point values, air inlets/outlets);
- Heating/cooling system;
- Design of functional areas; exercise yard/outdoor excess, grazing;
- Type of floor (solid/slats, material of the floor);
- Type of bedding material and amount, management, application;
- Manure system, management and treatment;
- Feeding technique and management;
- Feed composition (nutrients and ingredients) and feed additives;
- Type of drinking system.

The **detailed description of the system or technology** to be tested must include:

- A list of the (technical) components needed for application, including type (e.g. material and characteristics), technical and functional description and design;
- Description of the technique applied and the working principle;
- The system's function in detail and the expected performance of the system with respect to the effect on the pollutants (odour, ammonia, PM);
- Illustrations and/or diagrams of the system (top and sectional views, details if necessary);
- A list of the essential design and operational parameters (ranges) that are specific for the system to be tested and that are decisive for proper function, and that should therefore be monitored during the test (e.g. slurry acidification, pH, minimum amount of additives applied);
- A list of key parameters considered relevant for electronic or manual logging during operation of the system as part of system surveillance, which must include a description on how they are monitored;
- Compilation of the input materials needed and liquids and wastes produced (including amount and relevant chemical composition);
- Detailed instructions on operation, service and maintenance and monitoring.

If the applicant/manufacturer has had tests carried out on earlier models of the system, all the test reports must be enclosed, including a description of the differences between the models.

The manufacturer/applicant must provide general information about:

- Environmental, occupational, animal and food safety of the products applied;
- Essential parameters for the calculation of the uptime/downtime of the system (although the test institute is responsible for a professional evaluation of whether this information is reliable and sufficient);
- Predicted durability of the system and its components;
- Warranty provisions;
- A list of demonstration units already working (animal category, type of housing system, animal weights, ventilation rates in particular) if available.

The system must meet the minimum national requirements on animal health and welfare prior to testing.

User manual

A user manual for the technology must be available in the local language. It must be written in consideration of EN 82079 Preparation of instructions - Structuring, content and presentation, which provides general principles and detailed requirements for the design and formulation of all types of instructions, and Machinery Directive 2006/42/EC, which provides the regulatory basis for the harmonisation of essential health and safety requirements for machinery.

The user manual must include the information provided with the system description according to the descriptions above in this chapter and should, in particular, include instructions for:

- The operation of the system and the technical installations
- The prevention and handling of incidents (environmental safety)
- Operational health and safety measures
- Service and maintenance
- Monitoring of the installations.

7. Test requirements

This chapter specifies the requirements related to the testing of livestock housing and management systems.

In addition, the chapter describes the measurement parameters to be included in the test and a specification of the methods to be used and the people/organisations responsible for providing the specified information. Finally, the chapter includes requirements to ensure representative feeding and management conditions on the test facility, and requirements related to the impact of the technology on occupational health and safety as well as on animal health and welfare and on food safety.

Additional, more specific requirements and recommendations for some of these aspects are also referred to in the Annexes.

All more general requirements for testing and verification procedures, including the qualification of test partners, are specified in the **General VERA Guidelines** (GVG), which are publicly available on the VERA website www.vera-verification.eu.

7.1 Pre-testing or preparations for a full test of a technology

The test protocol can be used during the phases of developing a new technology (pre-testing), as well as for testing of a final technology (ready for commercial launch) with the aim of verification or to gain more basic information, e.g. on side-effects.

It is strongly recommended that pre-testing of a new technology is carried out before a full test is initiated, and a full test should only start when it has shown to be stable and functional.

During pre-testing of a technology, parts of the test protocol can be used in order to clarify and optimise the performance and operational stability of a new technology. The manufacturer may visit the test facility at any time during pre-testing.

However, during a full test of a technology with the aim of a VERA verification all the requirements mentioned in the following sections have to be fulfilled, including any general requirements stated in the General VERA Guidelines (GVG), requirements/restrictions on farm visits, and modifications of the technology.

The testing of a technology involves various actors:
1. The applicant wishing to have the technology tested
2. The test institute that carries out the required tests
3. The farmer(s) who own the facilities where the tests are carried out.

A detailed test plan is to be elaborated by the test laboratory according to the template in Annex L, including all relevant parameters.

The applicant/manufacturer is responsible for providing a full description of the system or the technology to be tested prior to the start of a full VERA test, cf. section 6. The description must include detailed instructions for operation, service, maintenance and surveillance.

7.2 Responsibilities during the test period

During operation, the applicant/manufacturer of the system is responsible for electronic logging of a number of key parameters to check the operation of the system. This logging must include those parameters essential for the calculation of the uptime/downtime of the system, cf. section 6.

The applicant/manufacturer of the technology is only allowed to visit the farm/company during the test period together with the test institute. Operational problems must be dated and described in the test logbook by the test institute. A logbook must be made available to the farmer and the test institute at any time during the test period. The test institute must also record the time spent on operational problems and maintenance of the system. In addition, a dated record must be made of when and how the problem was solved, and it should be signed by the test institute and the applicant/manufacturer when repairs have been completed.

The test institute is responsible for coordinating and implementing the test plan and for drawing up all the necessary data record tables. Furthermore, the test institute is responsible for calculation of the uptime/downtime of the tested system.

The farmer is responsible for recording the production conditions in accordance with the test plan. The farmer must also record the time spent on operational problems and maintenance of the system or the technology.

7.3 Test design, sampling and measurement strategy

7.3.1 Preliminary considerations on the basic principles

The emissions of ammonia, odour and dust are defined as the 'primary parameters' used to determine the environmental performance of the livestock housing and management systems tested. The design of the test and sampling strategy is based on:

- The expected effect of the system on the ammonia, PM and/or odour emissions;
- And is expressed in terms of the relative effect against a reference system and, if applicable, as an emission value.

Depending on the technology, the applicant may decide whether to test one or more of the emission-relevant parameters like ammonia, odour, dust and greenhouse gases simultaneously.

7.3.2 Selection of test design

The preferred test design is the case-control approach, as it is an effective way to minimise the effect of non-system factors (such as temperature, ventilation rate, animal feeding, age, etc.) between the control (without treatment) and case (with treatment) compartments. Only if the case-control approach is not feasible, for reasons specified below, the test design must be based on a multi-farm approach (multiple test locations without control compartments on the same farm).

Both the case-control and the multi-farm approach have a number of common requirements. These requirements, and the main characteristics and requirements of both test design types, are described in the following paragraphs.

Figure 1 provides an overview of the different options.

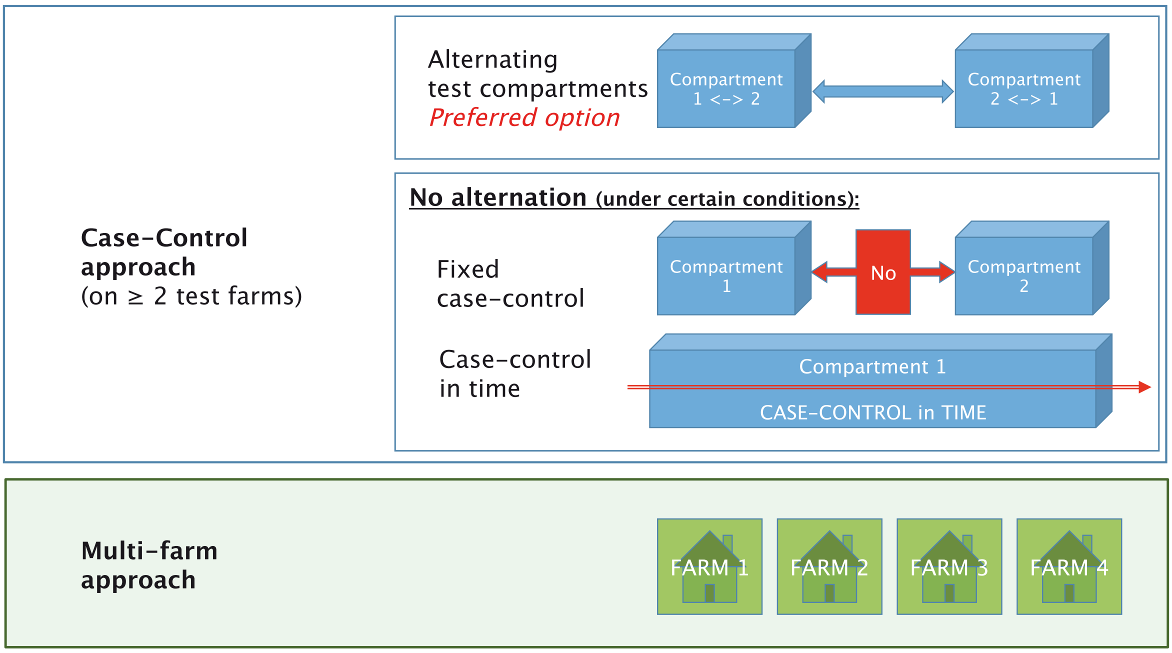

Figure 1: Options of test design.

Case-control test design

In the case-control approach, measurements should be performed in at least two test locations. At each test location (farm), two similar compartments will be needed: one equipped with the test system (case) and another one without the test system (control), in order to allow a direct comparison by carrying out simultaneous measurements. The compartments must be as similar as possible and must be located on the same farm to ensure equal management. The standard approach is to alternate case and control treatments between the compartments and measurement periods, unless this is not possible for technical reasons, as specified below. For recommendations on how to select the right test location, see Annex D.

The case-control study design can be applied to animal houses that are sectioned into compartments with separate ventilation and manure systems, as they are common in pig production for farrowing sows, weaners and growing/finishing pigs. In cases where housing units are not sectioned, comparisons may take place between equally designed houses at the same farm location. For example, in poultry production, broiler farms may have two or more identical houses that can be used for this purpose.

The case-control setup provides data that express the difference in emissions between the test system and the reference. The effect of the environmental technology can then be estimated as the overall mean difference between the emissions levels in the case and control compartments. Variance levels may differ between emission components and animal categories.

If high variations or low emission-reduction effects are expected during the measurements, it may become necessary to increase the number of measurements in order to achieve a statistically significant effect for the investigated technology.

All relevant non-system factors that may affect emissions (temperature, ventilation rate, animal number and age, feed, etc.) are to be kept as similar as possible between case and control compartments.

- The deviation of emission-relevant factors related to the compartment must be levelled out to less than 5% difference when alternating the compartments in the end.
- Allowed deviations in average animal weight (Table 1):

Table 1: Maximum deviation in average animal weight.

Animal type	maximum deviation in average animal weight
Fattening animals with linear increase	20% (10% for piglets)
Fattening animals with exponential increase (broilers)	5% (as all-in-all-out management is common practice)
Other animal production systems	10%

Case-control approach without alternating

If alternating compartments is not possible, there are two alternative options to the classical case-control or multi-site approach:

1. **Fixed case-control approach:** In situations, e.g. when installing/de-installing the system may not be affordable, alternating compartments may not be a feasible option. In this case, the compartments should be as similar as possible (e.g. animal numbers/age/weight, management).
   - The feed and ventilation system including management (climate control) must be identical.
   - The average animal weight must not exceed a maximum deviation of 5%.
   - The animals must be equally distributed in the compartment.

   In this specific approach, a baseline measurement of the emissions of both compartments before the system is installed in one of the compartments is required (for at least six measurement days within two months). This measurement is in order to quantify compartment differences (systematic differences, emission bias). The measured emissions during the case-control measurement periods have to be corrected accordingly for this emission bias in case there are significant differences between the compartments.

2. **Case-control in an 'On-Off' approach.** If the system being tested can be efficiently switched on and off within a maximum of two weeks, the 'On-Off' or 'case-control in time' approach may be used. The time for the adaptation of the system will also need to be considered.

   This requires measuring the emissions of the control (system off) and the case (system on) consecutively, rather than simultaneously. This method is only acceptable when they fulfil the following criteria:
   - The number and weight of the animals are stable.
   - System conditions are stable before the measurements begin. In some cases, this may lead to a delay of a couple of days before measurements by other situations (on-off) can start.
   - The measurement conditions (agronomic requirements, ventilation regime, etc.; cf. Annex B and section 7.3.3.2) must be similar for both measurement periods.

Multi-farm test design

When a case-control within a farm study design is not possible, the multi-farm approach shall be applied.
In this case, at least four test farms at different locations must be selected and equipped with the system, and then monitored during the required test period. The emission values are calculated accordingly and will be successively compared with a reference, either with a representative number of a minimum of four reference farms, which is the preferred option, or with a norm emission factor if available.

Similar to the case-control approach, in the multi-farm test design, the distribution of the (minimum) six sampling days throughout the year will depend upon the emissions pattern of the animal category being considered (cf. section 7.3.4). The procedure for the selection of sampling days is similar to the procedure described for the case-control test design.

7.3.3 Requirements on the test facility

The three most important questions that need to be answered regarding the suitability of test sites to perform emission measurements is whether the site is measurable, whether it is representative of the housing or management system being investigated and whether it fulfils the agronomic requirements.

7.3.3.1 Measurability of test site

In order to achieve reliable results, it is important that the selected test sites are suitable. Situations may vary both between and within countries due to the high variability in barn design and localisation of other emission sources near the test sites.

Measurability is essential when measuring in naturally ventilated buildings.

The following aspects have to be taken into account:
- The impact of other emission sources. This depends on distance, source type, strength and wind direction. This must be considered for all relevant emission compounds including CO_2 – especially when natural tracer gases are used to determine the air exchange rates. Both the gas concentrations in the air leaving the house (outgoing air) and the concentrations entering the house (incoming air) must be quantified in the presence of other sources close to the house.
- Test compartments on the same site (case-control approach) have to be isolated from each other in order to prevent any air exchange between the compartments.
- If a large number of animals are spending some time outside the house (e.g. the exercise yard and/or grazing or milking in a different building), the tracer gas used to estimate the ventilation rate must not be directly affected by this measure. CO_2 produced by the animals in the test compartments cannot be used as tracer gas in these cases (cf. section 7.4.2).
- If the distribution of animals inside the house is not uniform, the measurement points (and injection points when working with an artificial tracer gas) must be selected in such a way to account for this non-uniform source distribution (cf. section 7.3.5.3).

A guideline with pictures and recommendations for the selection of a suitable test site is provided in Annex D.

7.3.3.2 Representativeness of test site

The livestock housing and management system must be tested under farm conditions that are representative of the standard practices of the animal categories for which the system or technology is intended for use. This implies certain requirements for both the design of the test site and the management and measurement conditions during the test period.

Annexes B and C show both the mandatory and the national agronomic requirements between the standards in some of the VERA member countries, as well as a common baseline on a ‘standard housing system’.

Conditions of the test site and agronomic requirements

- The following items must be considered:
- Size of the LUs involved in the test, minimum/maximum size;
- Stock density and composition;
- Pen design, design of exercise yard, if applicable;
- Manure removal system;
- Ventilation system, management, design and dimensions in relation to number of animals.
    - Ventilation regime must be in line with established regional practices and regulations, and must ensure that the CO_2 concentration does not significantly exceed 3000 ppm.
    - Modification of the ventilation regime (e.g. reducing the inlet openings) must not interfere with the ‘standard conditions’, unless this is part of the specifications of the housing/management system being tested.
- Feeding system and ration – representative protein and energy ranges;
- Production level – representative performance ranges;
- Health management and medicine use. Absence of use of feed/manure additives or medical additives that may affect emissions must be declared.
- Technical management factors that may affect emissions (e.g. manure mixing, milking and grazing of dairy cattle) must be recorded. If the housing/management system is expected to have a big impact on these factors then the measurement strategy must be modified to take this into account.
- Climatic conditions during the measurements – avoid extreme meteorological conditions like heavy storms or extremely cold/hot weather.

Animal production must be in compliance with all relevant regulations at all times, e.g. in terms of animal health and welfare and operational safety.

Standard practices may differ between countries. The applicant must consider the most important criteria for their customers and follow the minimum requirements for animal production within the categories, as described in Annexes B and C. This measure is to improve the transferability of the data by allowing the authorities to extrapolate results to ‘typical’ housing systems at a later date.

During the test, a number of farm parameters related to these requirements must be recorded to verify standard practice. These are listed in Tables 6 and 7.

7.3.4 General sampling strategy

The sampling strategy includes the number and distribution of measurements in time, within and between farm locations.

Table 2: General sampling strategy.

Parameter	Minimum requirement
Number of compartments/housing units for sampling	**Case-Control design:** two different farm locations (cf. section 7.3) **Multi-farm approach:** four different farm locations
Minimum size of units for sampling	The unit size must be representative for farms in the participating countries.
Measurement periods	At each farm location: **For ammonia, odour and dust:** • ≥ six independent measurement periods of at least 24 hours distributed over one year, depending on the emission pattern (see below). ***For odour (specific for DK when using multi-farm approach)*** *• ≥ six independent measurement periods with outdoor temperatures above 16 °C during sampling.* *All odour samples sampled at temperatures above 16 °C may be included as part of the required minimum of six additional odour samples for acceptance of the tests in Denmark.*

The distribution of the sampling days depends on the emission pattern of the animal category being considered. Related to the growth of the animal, the pattern may remain stable or may increase linearly or exponentially. Table 3 shows the requirements for the different emission patterns.

Table 3: Sampling requirements depending on emission patterns.

Emission pattern	Example	Requirements for sampling per test location
Stable/constant	Dairy cattle	• Equal distribution over one year: The year is to be divided into periods of equal length. The number of periods must be identical to the number of measurement days: e.g. for six measurement days that is a measurement day once every two months. • Measurements must be independent.
Linear increase	Fattening pigs	In addition to stable patterns: • 50% of the sampling days in the first half of the production cycle. • 50% of the sampling days in the second half of the production cycle. • Sampling days in the second half of the production cycle should be equally distributed throughout the year.
Exponential increase	Broilers	In addition to stable patterns: • The production cycle is to be divided into three periods of equal length (same number of days). • 1st period: at least one sampling day. • 2nd period: at least two sampling days. • 3rd period: at least three sampling days equally distributed within the year. An example of the distribution of sampling days within the year and the production cycle (for broilers, with an exponential increase in emissions during the production cycle) is presented in Annex E.
All		For sites with exercise yards and/or grazing: Measurements shall only be performed with animals inside the house for the entire time.

Sampling material for gases
When using a sampling line, the material being used must be specified. For instance, polyethylene (PE) or polytetrafluoroethylene (PTFE) can be used. For SF_6, NH_3 and CO_2, adsorption/desorption must be minimised.
The gas recovery of the sampling system should be tested (see Annex G).
In case of temperature differences along the sampling lines where condensation may occur, insulation and heating of the sampling tubes will be required.

7.3.5 Measurement strategy

7.3.5.1 General

Calibration, verification and validation
For some measurement parameters, more than one measurement technique is listed in this VERA test protocol. These can be considered to be approved for the use in a VERA verification. Some techniques for the primary and for the secondary measurement parameters CO_2, N_2O and CH_4 are explicitly referred to as **'reference method'**, which shall be used to verify measurement data and validate other methods.

Each configuration of a measurement equipment has to be validated according to the reference method specified in this protocol. The validation can be performed according to EN 14793 or similarly suitable methods approved by VERA.

The calibration of measurement instruments is an essential part of the definition of the configuration.

This relates to calibration procedures that are only performed perennially or annually, as well as for those that need to be done before each use. The calibration must also take into account possible cross-interference from other gases in the test house, in addition to temperature, relative humidity etc.

Verification, within the meaning of on-site control, of the measurement technique/equipment used has to be performed on the test site, in combination with a more precise measurement technique than the one used.

Any calibration and verification procedures and estimates of the measurement uncertainty for the relevant parameters must fulfil the requirements of the ISO 17025 and be documented and reported.

Permitted deviation from the test protocol
If it is known that the type of environmental technology tested does not reduce a specific parameter or has only a marginal effect on it, the manufacturer/applicant can decide to specify the pollution reduction for this specific parameter as zero without carrying out the prescribed measurements.

However, the test report must show that in all probability, based on previous research, theories or test results, the environmental technology does not have any negative effect on the specific parameter.

Regulations and guidelines
When performing a test according to this test protocol, all activities shall be carried out in compliance with relevant national and EU legislation in force, as well as relevant standards.

Special attention should be paid to the following aspects:
- Occupational health and safety
- Animal health and welfare
- Food safety
- Chemical regulation

Lists of relevant EU directives as well as international standards within these fields are available in the bibliography of this test protocol and on the VERA website at http://www.vera-verification.eu/en/technology-manufacturers/test-protocols/ under 'Links to EU directives and international standards'. Note that the list may not be exhaustive, and that national legislation and standards are not included.

7.3.5.2 Measurement strategy for mechanically ventilated buildings

Mechanically ventilated animal houses are characterised by well-defined inlets and outlets, in which the air is well-mixed and leaves the facility via the installed ventilation outlets.

The emission can be determined in two ways:

- By measuring the ventilation rate as well as the concentration outside (background) and inside the building at the ventilation shafts. Emissions from mechanically ventilated buildings are calculated as the product of the amount of air leaving the building per unit of time (V; ventilation rate) and concentration in the outgoing air of the pollutant being measured (C_{out}) corrected by its concentration in the incoming air (C_{in}):
- $E = V \times (C_{out} - C_{in})$
- By using a calculation method based on the ratio of measured concentrations of the primary parameter (e.g. ammonia), a tracer gas inside the facility and the injection rate of the tracer gas. See section 7.4.2.3 for how emissions are calculated.

7.3.5.3 Measurement strategy for naturally ventilated buildings

Emissions can only be determined by using a calculation method based on the ratio of measured concentrations of the primary parameter, an artificial/natural tracer gas released/volatised inside the facility, and the injection/production rate of the tracer gas.

The tracer gas ratio method is described in section 7.4.2. The following aspects must be taken into account when defining a measurement strategy for naturally ventilated buildings (recommendations and examples to these items are given in Annex F):

- Positioning of sampling/measurement points in the house (this can vary depending on the design of the animal house).
  - The distance between the sampling point and the side wall or an outlet opening shall be at least two metres.
  - A height of at least three metres is required to minimise the effect of animals, cubicles and other obstacles.
  - Obstacles inside the animal house must not affect the representativeness of the measurement point (e.g. by changing flow patterns).
- Number of measurement points: at least one sampling point per ten metres of barn length equally distributed in the house.
- When using a sampling line with multiple sampling points, sampling points need to be provided with a critical orifice in order to allow a constant and controlled sampling flow rate, and a dust filter (except for dust measurements). The performance of the pump has to be adapted to the length of the sampling line and the total number of orifices in order to assure the same air flow of all orifices.
- In order to minimise the effect of the inside air being sampled in the outside air, measurement points shall be placed at a distance of at least five metres perpendicular to the sidewalls in order to measure the gas concentration of incoming air.
- At least one sampling point outside the building (at all open sidewalls) must be placed. If there are any other sources which might influence the emission of the animal house then additional sampling points will be required (examples are provided in Annex F).

7.4 Measurements

7.4.1. Measurement parameters

The measurement parameters are split into primary and secondary parameters, which are either related to the emissions or to other factors like the level of production and operational stability of the system in test.

Primary parameters
'Primary parameters' include the primary environmental pollutants emitted from the livestock housing unit and are the primary targets of the environmental technologies for livestock production. In this protocol, these primary parameters are ammonia, odour and dust emissions, which are presented in Table 4 together with units, sampling conditions and measuring methods.

Table 4: Primary measurement parameters.

Parameter [Units]	**Sampling conditions** (where, how and how often)	**Measuring method** Standard reference method for validation according to EN 14793 or similar.
Ammonia [mg m^{-3}]	• Cumulative sampling up to 24 hours • Continuous measuring methods: based on hourly values (24 samples) • Sampling location: see section 7.3.5.2 and 7.3.5.3 • Correction of background concentration	Impinger system (prEN/DIS 21877, NEN 2826, VDI 3496).
Odour [OU_E m^{-3}]	• Minimum three samples per sampling day • Sampling between 9 am and 4 pm • Sampling time: Between 30 and 120 minutes • Sampling equipment: polyethylenterephthalate, polyvinyl fluoride or polytetrafluoroethylene bags • Sampling location: Cross-section of air outlets, preferably mixed sample	EN 13725 Air quality – Determination of odour concentration by dynamic olfactometry. *(Note: in NL, the use of the forced choice response method is obligatory for the Dutch 'Regeling geur en veehouderij (Regulation on odour and livestock))*
Particulate matter (PM) [mg m^{-3}]	Measurement of PM10 and a larger fraction (e.g. 'TD', 'ID') is mandatory. PM2.5 is optional for methodological reasons. • Cumulative sampling over 24 hours • Continuous measuring methods: based on hourly values (24 samples) • Sampling time: 24 hours for PM10/PM2.5 • Sampling location: Air inlet and air outlet • Use duplicates at each sampling point	The exact PM fraction that has been sampled has to be reported, i.e. either by referring to a fraction (e.g. PM10, ID), by mentioning its 50% cut-off diameter or by giving its cut-off curve. Standards for measurements according to (see bibliography for details), e.g. • ISO 7708 and EN481 (for inhalable dust, PM100) • 40 CFR 50, appendix B (for TSP, PM35) • NIOSH Method 0500 (for total dust) • EN 12341 and EN 13284-1 (for PM10) • EN 14907 (for PM2.5)

For measurements of the PM, the following considerations should be taken into account:

The measurement methods should produce concentrations near the true concentration. Systematic bias of the measurement methods can be severe. Even in cases where measurements are meant to produce a PM emission-mitigation efficiency 'only' on a relative scale (i.e. determined from the PM emissions of a treatment house and a control house), it is questionable if the resulting efficiency, where the systematic error would be cancelled out, reflects the performance in practice.

Measurement methods can only be used after equivalence tests to relevant reference samplers have been carried out, and corrective measures have been taken. Such measures may, for instance, include the recalibration of a method using the PM of interest or the use of correction factors. No standard is currently available that describes how to perform equivalence tests in livestock production settings. The standards listed in the bibliography, especially EN 12341, provide guidance, for instance, with regard to reference samplers, general procedures and statistical tests.

Measurement methods based on light-scattering must not be used under very humid conditions, such as downstream of heat exchangers or manure drying systems. The uptake of water by the particles can interfere with the working principle of light-scattering. In these cases, a gravimetric method is the best option currently available. Light-scattering devices can only be permitted when the conditions mentioned above have been met and duplicate samplers to reduce random error are used as well as the systematic bias has been corrected by recalibration or by the use of correction factors.

Secondary parameters

Secondary parameters are either related to the emissions or to other factors like the level of production and operational stability of the system being tested. Depending on their impact, they are either mandatory or optional.

Secondary measurement parameters are categorised in the following three tables:

- Parameters that (might) influence the emissions level of the primary environmental pollutants, or which are relevant reference values (Table 5);
- Parameters related to the animal/manure/feed composition (Table 6);
- Parameters related to the operational functioning system (Table 7).

Table 5: Secondary measurement parameters related to gaseous emissions and climate.

Parameter [Units] (M) = Mandatory (O) = Optional	**Sampling conditions** (where, how and how often)	**Measuring method** (cf. section 7.4.2, standard reference method for validation according to EN 14793 or similar)
Ventilation rate (M) [$m^3 h^{-1}$]	• Ventilation rate through all air outlets (only possible in mechanically ventilated buildings) • For naturally ventilated buildings (cf. section 7.3.5.3)	<u>Mechanical ventilation:</u> Calibrated fan-wheel anemometer <u>Natural ventilation:</u> Tracer gas method (cf. section 7.5).
CO_2 (M) [$mg\ m^{-3}$]	• Continuous measuring methods, based on hourly values (24 samples), or time-averaged sample over a 24-hour sampling period • Sampling location: - mechanical systems: air inlet and air outlet - naturally ventilated: cf. section 7.3.5.3 • Correction of background concentration	• GC-TCD (use a column with a good separation of gases)
Temperature (M) [°C]	• Continuous measurement. Minimum time: 24 hours on sampling days • Continuous measuring methods: based on hourly values (24 samples) • Sampling location: Air inlet and air outlet	Thermocouples or other calibrated temperature sensors • Adequate measuring range, sensitivity, detection limit • Consider undesired effects on measuring device through e.g. contamination, wind or direct sunshine
Humidity, relative humidity (M) [% or $mg\ m^3$]	• As for temperature	Capacity sensor or other calibrated humidity sensors • Consider undesired effects on measuring device through e.g. contamination, wind, water, direct sunshine or frost.
Wind (M only for naturally venti-lated buildings) Direction [°] Speed [$m\ s^{-1}$]	• Sampling as for temperature • For wind direction: measuring height 10 m (according to VDI Guideline 3786) or data from local meteorological station • Wind speed at inlet: approx. 2 m depending on the air inlet height	Ultrasonic anemometer, wind vane, cup anemometer, propeller anemometer Consider undesired effects on measuring device through e.g. contamination or wind shadows, frost
CH_4 (O) [$mg\ m^{-3}$]	• As for CO_2	GC-FID (use a column with a good separation of gases)
N_2O (O) [$mg\ m^{-3}$]	• As for CO_2	GC-ECD (use a column with a good separation of gases)

Table 6: Secondary measurement parameters related to the animal production unit size, manure and feed composition.

Parameter [Units] (M) = Mandatory (O) = Optional	**Sample conditions** (where, how and how often)	**Measuring method**
Number and weight of animals in housing unit [kg] (M)	Date, number and weight estimation at sampling days	Counting, weighing or estimation
Floor space per animal [m²] (M)	Type of floors (material, perforation, condition)	Documentation through recording
Air volume per animal [m³] (M)	Calculated based on volume of the compartment and number of animals	Documentation through recording
Manure parameters • Amount [m³] (M) • pH • DM [g kg^{-1}] • Organic DM [g kg^{-1}] • N, P and K [g kg^{-1}] • TAN [g kg^{-1}] • C:N • Additives/residues	Sampling at scheduled sampling days for emission measurements as a minimum Amount of manure (stored in the house) must be measured manually at sampling days (e.g. by height of the slurry level) Manure samples must be 'inactivated' immediately after sampling by: Storing samples in a cool box ≤ 5 °C until placed in a freezer Storing samples in the freezer within 5 hours of sampling	Laboratory methods The TAN content can be estimated using the procedure of the Danish normative system (Poulsen et al., 2001) **Comment:** Manure parameter measurements should be carried out for validation and explanation of emission values or effects of additives, if relevant for the technology tested. Manure amount is mandatory while the others are optional.
Dates of emptying the pits or manure channels (M)		Documentation through recording
Cleaning of animal house and dunging behaviour (M)	Description of cleaning procedure Registration of defecation behaviour in each pen on odour sampling days	Documentation through recording
Fouling /pollution of surfaces (pen and animals) (M)	Investigation during sampling days	Measurement Assessment/rating
Feed composition parameters (O) • Amount [kg] • DM [g kg^{-1}] • ME [MJ kg^{-1}] • P and K • CP and CF • Lysine • Additives • Feeding strategy and frequency	Samples of charge Sampling at scheduled sampling days for emissions measurements as a minimum, if possible. During the testing period the dietary protein content should be within specific ranges for different animal categories according to Annex B. The farmer must be able to document the actual crude protein level in the feed during the test period. If the farmer is not able to deliver this documentation, three feed samples must be taken spread over the measurement period and analysed. In the case of feed additives, the correct amount/dose must be verified.	Laboratory methods and documentation through recording **Comment:** Feed composition parameters should be measured when relevant for the explanation of the performance of the applied technology/system, e.g. for additives.
Animal production parameters (O, M: when using tracer gases) • Milk yield [kg animal^{-1} day^{-1}] • Egg production [kg animal^{-1} day^{-1}] • Days of pregnancy		Documentation through recording

Parameters for evaluating the operational stability

Table 7: If applicable to the specific technology, measurement parameters related to the operational functioning and stability of the system/technology.

Parameter [Units] (M) = Mandatory (O) = Optional	**Sampling conditions** (where, how and how often)	**Measuring method**
Consumption of electricity by the technology/ system [kWh] (M) Related to time	Continuous measurement of electricity consumption by ventilation in general and by the environmental technology	Documentation through recording
Consumption of water by the technology/ system [l],[m³] (M) Related to time	Continuous measurement	Documentation through recording
Consumption of chemicals/additives (e.g. acid) Mass [mg or kg] or Volume [l or m³] and related to space and animals [m²], [LU], [AP] (M)	Measurement/monitoring	Documentation through recording
Operational function and stability (M) Activities, special events (M)	Continuous measurement	Documentation through recording
Noise (O)	Outdoor 1–2 m from ventilation outlet	Noise level meter ISO 3746

7.4.2 Measurement methods

7.4.2.1 Basic principles

Most of the measurement parameters specified in this protocol are based on existing standards and guidelines. As emissions are mostly related to the volume flow, it is crucial to measure them with the highest precision possible. Depending on the test site, this can be challenging and may require specific conditions. The requirements for the most critical measurement methods are described in the following sections in more detail.

Apart from the test methods listed in Tables 4 to 7, other test methods may be acceptable if they are sufficiently validated against the respective reference method.

During the measurement of all the parameters described in Tables 4 to 7, it is essential to:

- Avoid absorption, adsorption, diffusion, condensation, leakages and blockages during sampling;
- Ensure constant conditions by considering delay time of sampling tubes, rising time and drying out time of measuring instruments;
- Consider potential cross-sensitivities of measuring instruments;
- Fit the effective range of expected values to the measuring range of instruments or fit the method to the effective range of expected values and avoid measuring close to the lower or upper detection limit;
- Carry out calibration and maintenance of instruments and methods, fulfilling the requirements of the ISO 17025.

7.4.2.2. Fan-wheel anemometer

The reference method to measure the ventilation rate from mechanically ventilated livestock buildings is by using commercial fan-wheel anemometers, which must be calibrated beforehand. The fan-wheel anemometer must cover the whole exhaust area and has to be placed in such a way that sufficient distances to the ventilator are respected (cf. Table 5).

7.4.2.3. Tracer gas ratio method

For naturally ventilated buildings the tracer gas ratio method is the reference method.

The tracer gas ratio method relies on the estimation of the emission of a pollutant (e.g. ammonia E_{NH_3}) based on the production/emission of a tracer gas (P_{tracer}) and the ratio of the concentrations of the pollutant (e.g. C_{NH_3}) and the tracer (C_{tracer}), corrected for outside/incoming air concentrations:

$$E_{NH_3} = P_{tracer} \times \frac{[C_{NH_3}]_{barn} - [C_{NH_3}]_{outside}}{[C_{tracer}]_{barn} - [C_{tracer}]_{outside}}$$

Selection of suitable tracer gas

For the tracer gas, either an artificial tracer gas or a metabolically produced tracer gas may be used. The following table is a tool for selecting the correct tracer gas:

Table 8: Selection of suitable tracer.

	Artificial tracer gas	Metabolically produced tracer gas
Most common gases	• SF_6 (can be measured in small concentrations (ppb) using a gas chromatograph equipped with an ECD. *Note: This is forbidden in Denmark for its high global warming potential)* • Krypton-85 (^{85}Kr) • Trifluoromethyl sulphur pentafluoride (SF_5CF_3)	• CO_2
Handling	• Production/emission of the tracer gas can be quantified accurately • Tracer gas injection, control and monitoring systems are needed • At least one injection point per 10 m² is necessary	• Estimation of metabolically produced CO_2 by using the calculation rules of the International Commission of Agricultural and Biosystems Engineering • (see VERA calculation template) • Correction for other CO_2 sources, e.g. from manure, if necessary (see Annex H)
Farms with deep litter systems	• Suitable	• Measurement data of the CO_2 contribution of the bedding material needs to be presented
Outdoor concentration	• Effects are usually negligible	• Spatially and temporally variable • Concentration in incoming air must be determined

<u>Artificial tracer gas method</u>

The tracer gas constant injection method is the most commonly applied artificial tracer gas method. The general details of this approach are explained in Annex F.

In order to get a representative emission estimate, the following must be taken into account:

a. The tracer gas must be chemically inert, thermally stable and must not react with other components in the house. Tracers and pollutants must have a similar dispersion from the source to the measurement point.
b. Both the injection rate (P_{tracer}) and the concentration inside and outside the building of both the tracer (C_{tracer}) and the pollutant being measured (e.g. C_{NH_3}) must be accurately monitored and must be measured at the same sampling points.
c. The tracer gas must be emitted close to the emission sources of the measured pollutant (cf. Figure 19 for artificial tracer), homogeneously distributed, and in a large number to mimic the emission process of the pollutant of interest.
d. Injection points are to be equipped with capillary tubes to allow the passage of a specific and similar amount of tracer gas per injection point.
e. One injection point per approximately 10 m² of emitting surface, equally distributed.

CO_2 tracer gas ratio method

This method relies on concentration measurements of the pollutant (e.g. C_{NH_3}) and the tracer CO_2 in the incoming (outside air, background) and outgoing (barn) air, and on the estimation of the CO_2 production (P_{tracer}) from animals (PCO_2 (animals)) and manure (PCO_2 (manure)) in the barn:

$$P_{tracer} = PCO_2\,(animals) + PCO_2\,(manure)$$

The CO_2 production from the animals at house level (PCO_2 (animals) standard; m^3 CO_2 h^{-1}) for standard conditions (indoor temperature of 20 °C) is based on heat production of the animals and the consequent production of CO_2, determined using the calculation rules according to Annex H)

For farms with deep litter systems, measurement data on the CO_2 contribution by the bedding material must be presented.

Table 9 summarises the main variation factors and states which factors are already estimated in the CIGR calculation rules, and which factors need to be measured. All details are provided in Annex H.

Table 9: Variation factors in the CO_2 balance method.

Prediction factor	Estimate by CIGR rules	Required data
Animals	Included	Number of animals, production parameters
Temperature	Included	Measurements
Slurry	Included	Default value
Deep litter/ Bedding	Correction needed	Measurements
Animal activity	Not included	Correction optional

A sample calculation spreadsheet for these equations for measurements in dairy cow houses is provided on the VERA website.

7.5 Data treatment, calculation and evaluation of emissions

For each measurement parameter, the necessary units expressing the results are specified to ensure the highest possible comparability of the results and a sufficient information basis for recalculating, reproducing, converting and relating of values.

7.5.1 Completeness of dataset for calculation of emission values

For the calculation of emission values, all measurement results in the complete sampling schedule have to be included in the calculations, with the exception of:

- Measurement results that are missing or unreliable because of equipment malfunction or unusual weather conditions, and where these measurements could not be replaced in time.
- All measurement results of a sampling day for which less than 80% of the measurement data for the day are available as a result of equipment malfunction.
- Measurement results during which the test location did not comply with the required management conditions, stated in Annex B and section 7.3.
- Measurement results that can be considered outliers after statistical analysis (e.g. for normal distributed data by the Grubbs test as suggested in EN 14793, or by using the boxplot method with three times the interquartile range as shown in Figure 2) of the daily means of the complete dataset.

Q1: Lower (first) quartile (25%)
Q2: Median (second quartile)
Q3: Upper (third) quartile (75%)

IQR = Q3-Q1

Outlier if: value > Q3+3*IQR
OR value < Q1-3*IQR

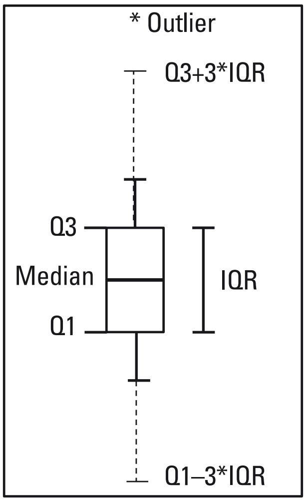

*Figure 2: Outlier test according to 3*IQR boxplot method.*

7.5.2 Calculation of mean daily emissions

Mean emission per time unit

As a first step, the **ammonia and dust emissions** are calculated at the smallest common time basis of measured concentration and ventilation rates. The common time basis may differ between tests as a result of using different analysers. These values are then used to calculate daily emission means. If more days per measurement period are measured, a mean for each single day has to be calculated first, and the mean of these daily values will be used as a result.

Emission (E) in test compartment (i) at sampling day (j) during time interval (= smallest common time basis) (k) is calculated from the ventilation rate (V) and the difference between concentrations in outlet and inlet (C_out, C_in):

$$E_{ijk} = V_{ijk} \times (C\_out_{ijk} - C\_in_{ijk}) \qquad (1)$$

In eq. 1, the following units are used for ammonia and dust:

- Concentrations in the inlet and the outlet: $g\ m^{-3}$
- Ventilation rate: $m^3\ h^{-1}$ animal^{-1} or $m^3\ h^{-1}$ LU^{-1}
- Emissions: $g\ h^{-1}$ animal^{-1} or $g\ h^{-1}$ LU^{-1} (not for animal products with exponential growth).

Similarly, odour emissions are calculated from the ventilation rate and the mean odour concentration (C_out) in the outlet taken at day (j) during sampling interval (k) as:

$$E_{ijk} = V_{ijk} \times (C\_out_{ijk}) \qquad (2)$$

In eq. 2, the following units are used for odour:

- Concentration in the outlet: $OU_E\ m^{-3}$
- Ventilation rate: $m^3\ s^{-1}$ animal^{-1} or $m^3\ s^{-1}$ LU^{-1}
- Emissions: $OU_E\ s^{-1}$ animal^{-1} or $OU_E\ s^{-1}$ LU^{-1}.

Mean daily emission

As a next step, the mean daily emissions E_{ij} for compartment i during sampling day j are calculated from E_{ijk}.

$$E_{ij} = \overline{E_{ijk}} \qquad (3)$$

The daily means have to be tabulated in the report for each test location. The daily means are used as input data for statistical evaluation, where relevant, and for calculation of annual emission values.

7.5.3 Statistical evaluation and emission values

Because of the partly different structure of the datasets, the statistic evaluation and calculation of annual emission values are described separately below for the case-control approach and for the alternative multi-site approach with at least four farm locations.

When emission values are reported, they must be provided in the following units:

- Dust: g dust $year^{-1}$ $animal^{-1}$ or g dust $year^{-1}$ LU^{-1}
- Odour: OU_E s^{-1} $animal^{-1}$ or OU_E s^{-1} LU^{-1}
- Ammonia: kg NH_3 $year^{-1}$ $animal^{-1}$ or kg NH_3 $year^{-1}$ LU^{-1}

Ammonia emissions may, in addition, be expressed relatively as a fraction of total excreted ammonia-N from the animal; and it must be taken into account that the emission of ammonia from a livestock housing system is affected not only by the housing design and management, but also by the manure composition. The latter is a dynamic factor and will change over time due to changes in feed composition and strategy, animal genetics, animal productivity, etc.

Case-control approach: Statistical evaluation

The purpose of the case-control approach is to estimate the proportional effect of the test housing system (case) on the emissions in relation to the reference housing system (control). Thus, the annual emissions of both the test and reference housing systems have to be calculated according to the procedure specified below.

<u>For animal categories with a stable emissions pattern or with a linear increase in emissions:</u>

- For each test location i the daily emission means E_{ij} are averaged over the whole sampling period, and this mean value is converted into the required units. This is done for both the control ($E_{control\text{-}i}$) and the case ($E_{case\text{-}i}$) compartments.

<u>For animal categories with exponential increase in emissions:</u>

- The production cycle is divided into three periods of equal length (same number of days), as shown in section 5.5. Within each period, the mean emissions are calculated from the available daily mean values (periodic means).
- The emission values for each test compartment (control and case) are calculated as the average of the three periodic means for both the control ($E_{control\text{-}i}$) and the case ($E_{case\text{-}i}$) compartments.
- As medians are used in input parameters in dispersion models, it is also advisable to report the medians of the odour emissions, using the same procedure as described before.

For each test location i the proportional effect [%] of the treatment (case) is calculated according to:

$$\frac{E_{control\text{-}i} - E_{case\text{-}i}}{E_{control\text{-}i}} \times 100 \qquad (4)$$

A statistically significant reduction at each farm location is required to obtain a verified emissions reduction, and if that precondition is fulfilled then the overall proportional effect is calculated as the average of each location mean.

For ammonia and dust, the means and standard deviations of the case and control compartment must also be reported for each test location.

Multi-farm approach: Statistical evaluation

The purpose of the multi-site approach is to calculate the annual emissions (emission values) of the housing system tested. For animal categories with a stable emissions pattern or with a linear increase in emissions, mean emissions within each test location, averaged over all the sampling days, and the standard deviation of these means are calculated and reported. The overall emissions for the housing system are calculated as the average of all location means.

For animal categories with experimental growth, the same procedure as in the case-control approach must be applied, i.e. a weighted mean of the three test periods for each test location should be calculated. The annual emissions are then derived from the mean value from all test locations.

For animal production with production gaps during the year, the annual emissions must be corrected for animal occupancy. The following equation provides an example for fattening pigs to convert the hourly values into annual values per animal place (AP):

$$E(\text{kg } NH_3 \text{ a}^{-1} \text{ AP}^{-1}) = E(\text{g } NH_3 \text{ d}^{-1} \text{ pig}^{-1}) \text{ x } 365 \text{ x occupancy x } 1/1000 \qquad (5)$$

With

- 365 To change from day to year
- occupancy To take into account the period where houses are empty.
  The occupancy varies between countries (in NL: 90%, others 95%)
- 1/1000 To change from g to kg

And assuming that pig = animal place

8. Test report and evaluation

This paragraph describes the requirements on the test report, including formalities for system and test description, data handling, statistical analysis, etc.

The test report must be written in English. The report must include chapters with the subheadings listed below. The following text gives a description of the contents that must be included in the chapters and suggestions of the individual sections.

Foreword

The foreword should include:

- a description of the three parties involved in the test – the applicant, the test institute and the farmer(s) – and their respective roles during the test period
- specification of the test period, including dates
- date and signatures of the person(s) responsible for the test
- name and address of the test institute.

Introduction

The introduction should include a motivating description of how the system/technology tested can meet these environmental challenges by decreasing emissions of environmental pollutants like ammonia, odour and dust, thereby reducing the overall environmental effect of the agricultural production system in question.

A general description of the technology or housing and management system, and of the applicant/manufacturer involved in the test will be included. If the applicant/manufacturer has performed previous tests, these must be described and references provided.

Materials and Methods

The materials and methods section must include a description of the following:

- The farms involved in the test;
- The housing and management system used (cf. section 6);
- Test design, including dimensioning of the test;
- The measuring methods used and their measuring uncertainty, including an explanation of why they were used and a validation report, if different from the reference method;
- A specification of the measurement instruments used, the measurement points and the measurement frequency (sampling procedure) and any calibration, validation and verification (= on-site control) procedures related to these;
- A description of calculation and statistical methods – including the statistical data processing, including models and handling outliers, if any, as well as the statistical software package, as defined in section 7.5.3.

The housing unit in which the test is performed must be illustrated by photos of the compartments and the animal house and details must be provided about the:

- Animal category;
- Dimensions of the compartments/pens or houses;
- Number of pens per compartment;
- Number of animals per compartment;
- Design of animal house: type of floor, manure system, feed system and ventilation system.

Results

The description of the results should start with specifications of the measured odour, ammonia and dust emissions, which are the primary target parameters of the test. The individual raw data (at least the daily means) must first be presented in graphs and then the processed data must be presented in tables as mean and average, with 95th percentiles as well as the results of tests on the significance of the treatment effects observed (cf. section 7.5 for guidelines on data treatment). The individual raw data in more detail must be made available upon request by the VERA verification body.

The average and standard deviation of the secondary measurement parameters (Tables 5 to 7) must be shown in tables and commented on in the text.

The results must contain a presentation of the results with the focus on documenting an environmental effect.

<u>For ammonia, greenhouse gases or dust emissions</u>

For each measuring day and housing unit, the following properties must be stated for sampling:

- Date of the measurement
- 24 hour average indoor temperature
- 24 hour average outdoor temperature
- 24 hour average ventilation rate
- 24 hour average concentration in inlets
- 24 hour average concentration in outlets
- Calculated 24 hour emissions

<u>For odour emissions</u>

For each measuring day and housing unit, the following properties must be stated:

- Date of the measurement
- Time at beginning of air sampling
- Duration of air sampling
- Indoor temperature during air sampling
- Outdoor temperature during air sampling
- Ventilation rate during measurement
- Measured odour concentration
- Calculated emissions

<u>Effects to be found in case-control test design</u>

The following properties must be stated:

- Calculated emissions per day from each compartment; and as the average for both case units and for both control units.
- P-value for t-test for calculation of the significance of differences between case and control for each pair of units.

<u>Operational stability</u>

An evaluation of the operating stability of the system must be given. This evaluation must be based on observations made during the entire testing period and must include all recorded data describing the stability of the system or technology.

The uptime of the system during the test period shall be calculated, as well as the efficiency of the technology corrected by the uptime factor. (Example: If the measured efficiency of a technology to reduce emission of ammonia is 90% and the uptime is 80%, the corrected efficiency of the technology is 72%.]

<u>Additional information</u>

Furthermore, the test report must include an evaluation of the potential risks which may be related to the use of the system, including potential impact on:

- Animal welfare
- Occupational health and safety
- Total (external) environment
- Food safety (e.g. feed additives)
- Chemical regulations, if relevant

These evaluations must include situations with normal operation of the system/technology and any unintended use or problem.

The test report must include advice to the authorities on how to inspect the system.
Finally, the test report must include an evaluation of the transferability of the results for their application to other types of animal housing units or other animal categories.

Upon request by the verification body, raw data must be made available by the applicant or the test institute for interpretation of the results and conclusions presented.

Discussion and conclusions
The results must be discussed in relation to aspects of the working principle of the system, the plausibility of the results and findings in related research reports.

The conclusions must sum up the major results and validate the housing and management system, and technology in general. The conclusions section should only include aspects that can be justified in the results section in the test report.

References
Relevant references must be specified.

Annexes
The raw data should be added in electronic form. An Excel spreadsheet for presenting the raw data is available on the VERA website.
Other Annexes can be added if relevant.

9. Bibliography

Applied standards:

General:

- **Directive 2006/42/EC** of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC (recast).
- **ISO 12100** Safety of machinery – General principles for design – Risk assessment and risk reduction.
- **EN 82079** Preparation of instructions – Structuring, content and presentation.
- **ISO 3746** Acoustics – Determination of sound power levels of noise sources – Survey method.
- **ISO/IEC 17025** General requirements for the competence of testing and calibration laboratories.
- **EN 14793** Stationary source emissions – Demonstration of equivalence of an alternative method with a reference method.
- **EN 15259** Air quality – Measurement of stationary source emissions – Requirements for measurement sections and sites and for the measurement objective, plan and report.
- **VDI Guideline VDI 3786, Blatt 13** Environmental meteorology – Meteorological measurements measuring station.
- **VDI Guideline VDI 3894, Blatt 1** Emissions and immissions from animal husbandry – Housing systems and emissions – Pigs, cattle, poultry, horses.

Particulate Matter (PM):

- **ISO 7708** Air quality – Particle size fraction definitions for health-related sampling.
- **EN 481** Workplace atmospheres – Size fraction definitions for measurement of airborne particles.
- **EN 12341** Ambient air – Standard gravimetric measurement method for the determination of the PM10 or PM2.5 mass concentration of suspended particulate matter.
- **EN 13284-1** Stationary source emissions – Determination of low range mass concentration of dust – Part 1: Manual gravimetric method.
- **EN 13284-2** Stationary source emissions – Determination of low range mass concentration of dust – Part 2: Automated measuring systems.
- **NIOSH Method 0500** Particulate not otherwise regulated. Total aerosol mass. *Manual of Analytical Methods (NMAM),* Fourth Edition.
- **40 CFR Appendix B to Part 50** Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High-Volume Method).

Odour:

- **EN 13725** Air quality – Determination of odour concentration by dynamic olfactometry.

Ammonia:

- **prEN ISO/DIS 21877:2018** Stationary source emissions – Determination of the mass concentration of ammonia – Manual method.
- **NEN 2826** Air quality – Stationary source emissions – sampling and determination of gaseous ammonia content.
- **VDI Guideline VDI 3496, Blatt 1** Gaseous emission measurements. Determination of basic nitrogen compounds sizeable by absorption in sulphuric acid.

References:

- **Pedersen, S., Blanes-Vidal, V., Heetkamp M. J. W., and Aarnink. A. J. A. (2008).** Carbon dioxide production in animal houses: A literature review. Agricultural Engineering International: CIGR E-journal. Manuscript BC 08 008, Vol. X. December 2008.
- **Poulsen, H. D., Børsting, C. F., Rom, H. B., and Sommer, S. G. (eds.) (2001).** *Kvælstof, fosfor og kalium I husdyrgødning – normtal 2000* (Nitrogen, phosphorus and potassium in livestock manure – norm figures 2000). JF Rapport nr. 36 Husdyrbrug, Ministeriet for Fødevarer, Landbrug og Fiskeri, Danmarks JordbrugsForskning. pp. 152. http://web.agrsci.dk/djfpublikation/djfpdf/djfhd36.pdf

Annexes

Annex A (mandatory): Additives

Definition of an additive

A substance that is used by a specific application method, as outlined below, with the intention of reducing the emission potential of various defined parameters such as ammonia, odour, hydrogen sulphide, methane, nitrous oxide and PM such as aerosols.

Types of additives include:
Acidifying agents
Oxidising agents
Disinfectants
Urease inhibitors
Adsorbents
Electrical charging of gaseous compounds and aerosols
Oil substances

Application methods include:
Application to animal feed.
Application to manure storage.
Application to bedding materials.
Addition to the inside air by direct sprinkling and fogging of additives, occasionally combined with internal air recirculation.
Addition of electrical charges to gaseous compounds and aerosols by corona.

Special demands for testing additives

The working principle of the additive in question must first be established. In practice, this proves to be a challenge particularly for microbial/biological agents. Therefore, mass balances for the additives and compounds of interest (e.g. ammonia, sulphurous compounds when ozone or other oxidising agents have been applied) must be presented.

Before starting full-scale experiments, it is advisable to conduct lab-scale experiments in order to assess the potential of the additive in reducing emissions from manure. This is a relatively low cost intermediate step that can prevent big disappointments after unsuccessful full-scale experiments.

For full-scale experiments, the case-control approach is the most meaningful for testing additives. Special care must be taken to eliminate effects that cannot be attributed to the additive in question. For instance, most additives are applied to the manure in a water solution. Adding water can have an emission-reduction effect (e.g. by dilution), which cannot be claimed by the additive. Therefore, the case-control setup needs to be smartly designed to account for these aspects. The test must be designed so it becomes clear that the doses or dosages of the additive can adequately explain the postulated effect.

Annex B (mandatory): Agronomic requirements for testing

Dairy Cows

Table 10: Agronomic requirements for dairy cows.

Criterion	Dairy cows
Herd composition	> 70% of the available barn area must be distributed to cows. *NL (mandatory): > 70% cows, < 30% heifers older than 1 year , <25% heifers on average over all measurement days, dry cows: < 25% of the total number of cows during all measurement days.*
Animal occupation rate of test compartment at all measurement days (%)	90–100% *NL: On top of this, a maximum of 10% of the cubicles (and related floor area) may be closed and left unused.*
Minimum number of animals in the test compartment	30 cows (milking + dry) for multi-farm approach 15 cows for case-control approach
Housing system in use before test	≥ 2 months
Feed composition	≥ 50% roughage
Feed requirements crude protein (CP)	≥ 160 g (or 160 – 180 g) CP per kg dry matter *(NL: lead to a milk urea content of ≥ 15 mg per 100 g)*
Minimum production requirements	25 kg milk cow^{-1} day^{-1}
Animal Welfare	Production must be in compliance with national animal welfare regulations.

Poultry

Table 11: Agronomic requirements for poultry.

Criterion	Laying hens	Broilers
Permitted weight range (kg)	-	0.05–3
Animal occupation rate of test compartment at all measurement days (%)	80–100%	80–100%
Minimum number of animals in test compartment	750	1000
Minimal period of use of housing system before testing	Two months	One batch
Feed requirements crude protein (CP)	DK: 16–18% CP DE: 15–20% CP	DK: 35–40 days/1.6–3 kg: 20–21% CP Outdoor; 56 days/2.4 kg: 15% CP DE: 17–23.5% CP
Minimum production requirements	300 eggs hen^{-1} $year^{-1}$	Min. 1900 g at max. 45 days
Animal welfare	Production must be in compliance with national animal welfare regulations.	

Dietary protein contents in poultry feeding (approximate values).

DK			DE		
Turkeys, females	10 kg live weight	20% CP	Turkeys	Week 1–5 (starter)	26–29.5% CP
Turkeys, males	20 kg live weight	18% CP		Week 6–16 (females)	18–24.5% CP
Ducks	4 kg live weight	17% CP		Week 6–21 (males)	14–24.5% CP
Geese	7 kg live weight	16% CP	Ducks	Week 1–2	20–24% CP
				Week 3–7	16–18% CP

Pigs

Table 12: Agronomic requirements for pigs.

Criterion	Sows	Farrowing sows/piglets	Weaners	Fattening pigs
Permitted weight range (kg)	-	-	6–35	25–115
Animal occupation rate of test compartment at all measurement days (%)	90–100	90–100	90–100	90–100
Minimum number of animals in the test compartment	20	10 sows	50	50
Minimal period of use of housing system before testing	Four months	One batch	One batch	One fattening period
Feed requirements crude protein (CP)	Pregnant: 11–14% CP	Lactating sow: 13–17% CP	< 20 kg: 18–21% CP > 20 kg: 17–20% CP	< 50 kg: 15–18% CP >50 kg: 14–16.5% CP
Minimum production requirements	22 piglets sow^{-1} $year^{-1}$	10 piglets per litter	350 g d^{-1}	760 g d^{-1}
Animal welfare	Production must be in compliance with national animal welfare regulations.			

Annex C (informative): 'typical dairy house' – common baseline

Description for a reference system

The most frequent housing system for dairy cows in the three VERA countries is:
Loose housing systems with cubicles

The building is divided into rows of individual cubicles where animals lie and rest, placed at one or both sides of a feeding area. These feeding and resting (cubicle) areas are normally provided with a solid concrete floor. The cubicles' solid floor area may be equipped with mattresses and may be strewn with some bedding material (straw, sawdust, wood shavings, sand, peat, manure fibre).

A slatted floor is frequently used in the walking and separation areas. However, the application of newly developed solid floors (e.g. grooved floors, sloping floors with urine gutters) is currently gaining interest.

Manure (faeces and urine) is mainly present in the form of slurry. Faeces and urine have to be removed regularly from the floor area (e.g. by using manure scrapers) into the manure pits (under the floor) inside the barn or into an outside manure storage. The amount of fouled surface per cow varies from 2.5 to 5 m^2 per cow. Typical manure pit depths (below slatted floor) range between 0.5 and 2.5 m.

Most loose houses are naturally ventilated. Air mainly enters the house through openings in the facade of the barn, and leaves the building through an open ridge or through openings in the walls.

Characteristics of housing systems for cows

Table 13: Standard housing systems for dairy cows.

Housing system	Loose housing with cubicles	Loose housing with deep litter
Prevalence of house type	Most frequent	Less frequent
Bedding type	Straw, sawdust, wood shavings, sand, manure fibres, (in some countries: mattresses)	Straw
Floor space – lying area	NL: 3–5 m^2 / DK: 2.5–4 m^2	Same as house with cubicles
Floor space – walking area	DK: 3–5 m^2	Same as house with cubicles
Floor type – walking area	Mostly slatted, sometimes solid	Straw and slatted/solid
Dunging system Manure pits under floor?	Yes, in barns with slatted floor. In barns with solid floor manure is stored outside.	Only in barns with slatted floor areas.
Manure removal	Manure scrapers	Manure scrapers on solid areas
Slurry pit area	Depth: NL: 2–2.5 m/ DK: 0.8–1.2 m	depth <1 m
Ventilation	Naturally ventilated	Naturally ventilated

Annex D (informative): Guidelines for the selection of a test site

In order to evaluate the measurability of a test site, especially when measuring a naturally ventilated building, the following aspects have to be taken into account:

- Other sources near the compartment to be measured may not make the test site measurable for particular wind directions (Figure 3).

It is important to accurately quantify not only the concentrations in the air leaving the house (outgoing air) but also the concentrations entering the house (incoming air). In the presence of other sources close to the house, and when wind is blowing from those sources, the incoming air concentration should be measured between these sources and the measured house/compartment. To avoid interaction of the house on the measurement points for incoming air concentration, these measurement points should be located at a distance of at least five metres from the inlet openings. If the source is too close to the house then this may not be possible. The site may not be measurable for that particular wind direction but may be measurable for other wind directions. This asks for a careful planning of the measurements and maybe a different measurement strategy (e.g. by placing measurement points for incoming air concentration at both sides of the house, and using (semi-)continuous measurement equipment to check whether the air is contributing to the measured incoming air concentration). When excluding particular wind directions in a measurement campaign, it is important to consider whether there is a risk that this exclusion may lead to biased results.

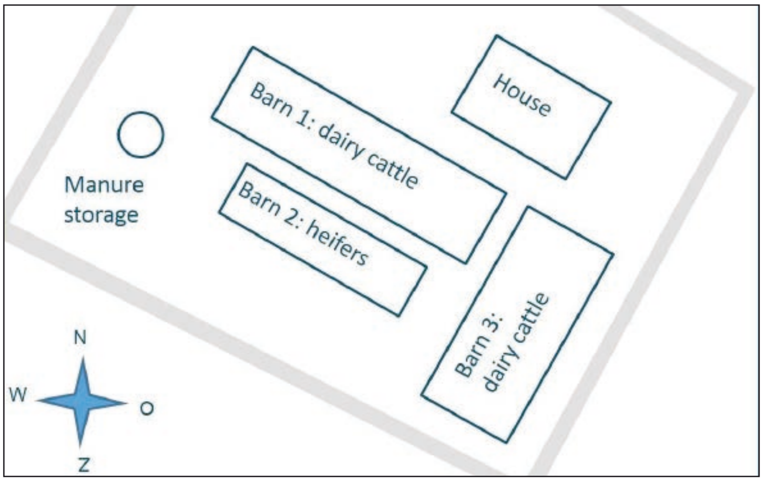

Figure 3: Barn 1, housing dairy cattle, is located Northeast of barn 2 (heifers), Northwest of barn 3 (dairy cattle), and Northeast of a manure storage. When the wind blows from the North, measurement of incoming air concentrations are straightforward. When the wind comes from the South, the measurement strategy for incoming air concentrations should be adapted to include measurement points between the barn and other sources nearby.

Most of these aspects could be checked by providing:

- An aerial photo of the test site, including other nearby sources (animal houses, manure storages, etc.).
- A schematic floor plan of the animal house explaining the layout of functional zones and ventilation design.
- Wind rose for the test site or a nearby location.
- If the compartment to be measured is directly connected to another compartment with air exchange between both compartments (Figure 4) then the test site, as such, is not measurable since it is not possible to differentiate between the compartments and the possible interactions.

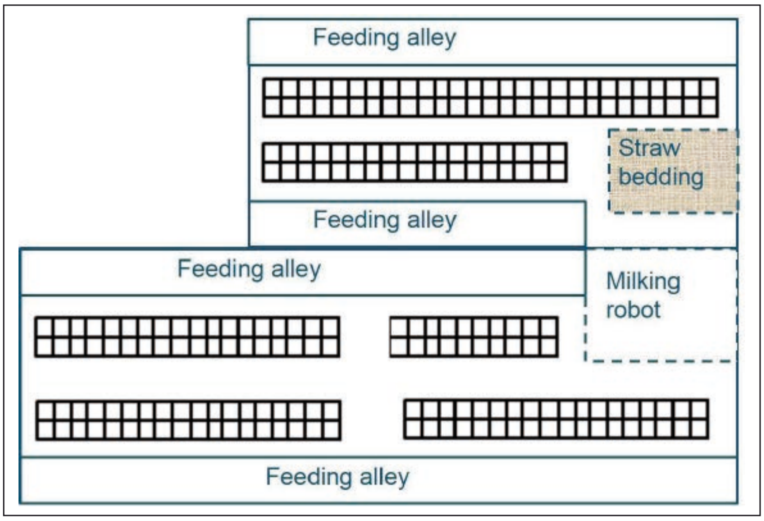

Figure 4: Cows go from Barn A to Barn B for milking. Both barns are connected, and air exchange between barns may occur even outside milking periods.

Figure 5: left, both barns are interconnected; right: the barns are isolated to avoid air exchange.

To make the test site measurable, both compartments have to be completely isolated from each other (cf. Figure 5):

- If a large number of animals are spending some time outside the house (e.g. for grazing or milking in a different building) then the site is measurable as long as the production of the tracer used to estimate the ventilation rate is not directly affected by this measure. In these situations, metabolically produced CO_2 cannot be used as a tracer gas (cf. section 7.4.2).
- Unused areas, but emitting surfaces, may be reduced by tight covers, as shown in Figure 6:

Figure 6: Closing cubicles and related floor area

Measurement conditions

- It is advisable to avoid performing measurements under extreme meteorological conditions (e.g. when the weather forecast for the area predicts high wind velocity or extremely cold/hot weather).
- Measurements have to be performed without any modification of the ventilation regime (e.g. reducing the inlet openings, as shown in Figure 7), unless this is part of the specifications of the housing/management system being tested. Changes in air movement inside the house due to changes in ventilation rate strongly influence the ammonia emissions from dairy barns).

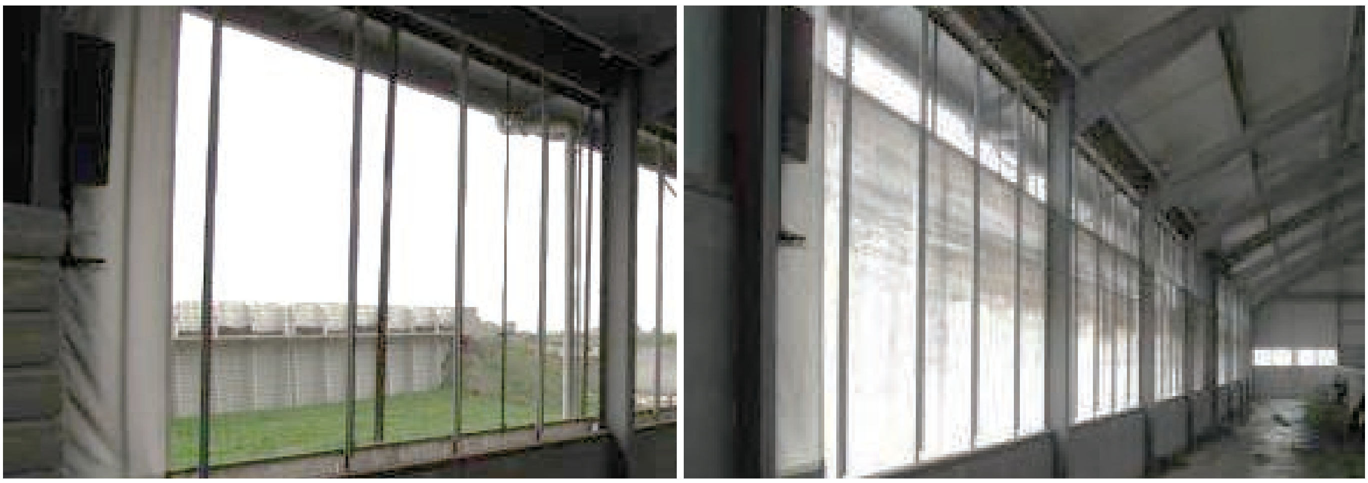

Figure 7: Two examples of air inlet openings. Left: curtains are almost completely open. Right: curtains closed to reduce ventilation rate.

Annex E (informative): Example of distribution of sampling days for broilers during one-year test

(Exponential increase in emissions during the production cycle)

Case-control test design (within a farm)

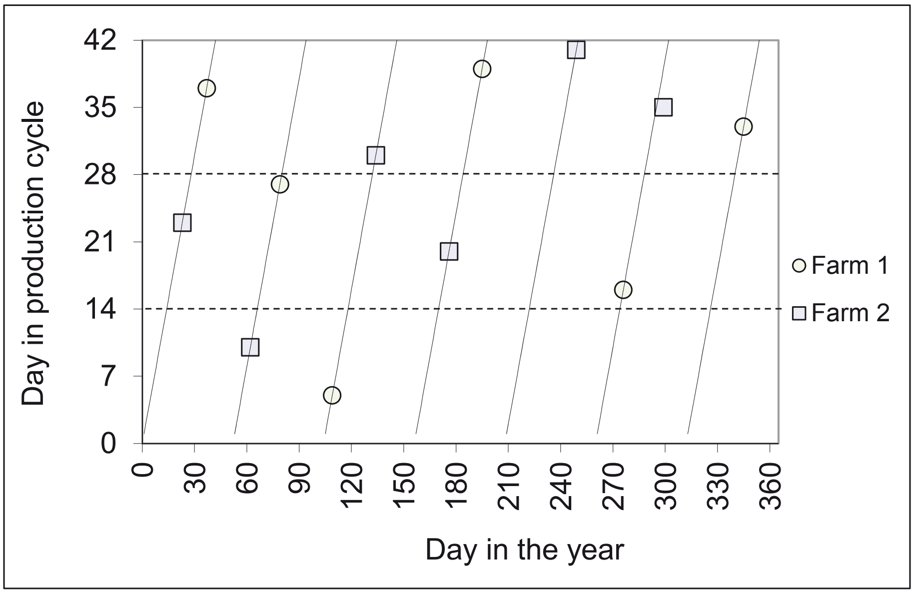

Figure 8: Distribution of sampling days within one year. In this example, a production cycle of 42 days for broilers is assumed. Case and control compartments are measured on the same day. The horizontal lines represent the division of the production cycle into three periods of equal length (same number of days), as stipulated in Table 3.

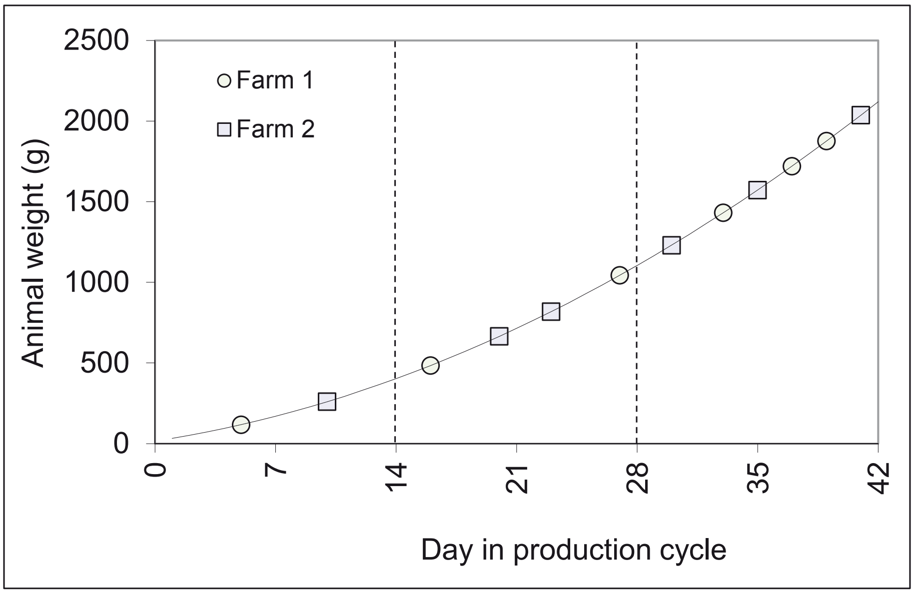

Figure 9: Example of distribution of sampling days within a 42-day production cycle of broilers. The vertical lines represent the division of the production cycle into three periods of equal length (same number of days), as stipulated in Table 3.

Test designs for multi-farm approach

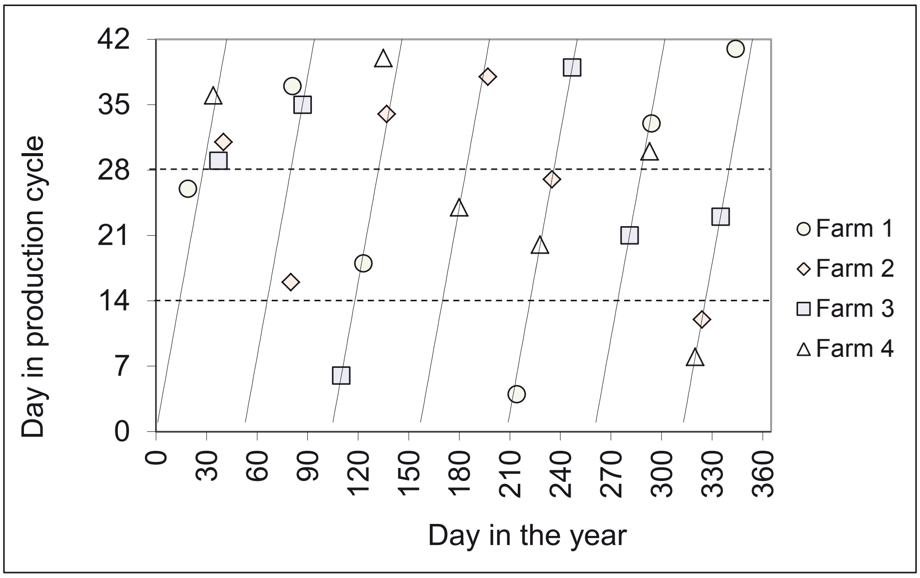

Figure 10: Distribution of sampling days within the year. In this example, a production cycle of 42 days for broilers is assumed. The horizontal lines represent the division of the production cycle into three periods of equal length (same number of days), as stipulated in Table 3.

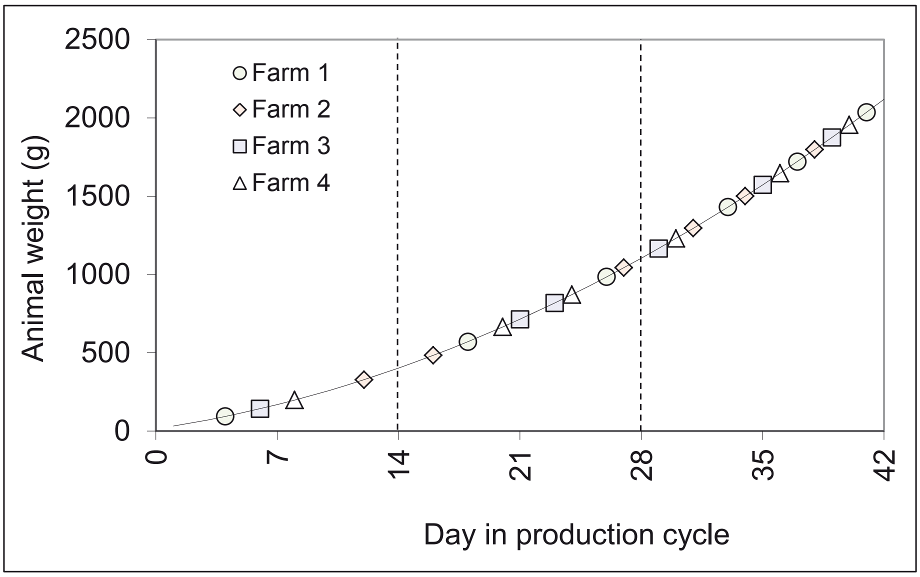

Figure 11: Distribution of sampling days within a 42-day production cycle of broilers. The vertical lines represent the division of the production cycle into three periods of equal length (same number of days), as stipulated in Table 3.

Annex F (informative): Comments and explanations on VERA test protocol

(Section 7.3.2): Advantages of a case-control approach

- A case-control setup is effective in terms of creating an optimal ratio between statistical accuracy and costs. In this setup, the disturbance effects of non-system factors that are similar in both case and control compartments at the same time are eliminated by observing the differences between case and control compartments.
- Transfer of results between countries can be facilitated by relating the observed relative effects to the national standard housing systems. A table of emission factors (measured and possible legal/allowable limits) for different animal categories can be found in Annex I for ammonia, Annex J for odour, and Annex K for dust.
- It is preferable to switch two or more times between the case and control systems if possible. The switch can be made by the swapping of new animals for growing animals, between emptying of manure systems, feed changes or what is most relevant for the test of interest.

(Section 7.3.5): Considerations on measurement strategy

Depending on the purpose of the measurements, the decision can be made to choose an integrated approach and to measure a combination of several emission-relevant parameters like ammonia, odour, dust and greenhouse gases simultaneously. The costs involved in the measurements is the main disadvantage of using an integrated approach. However, one of the advantages to using an integrated approach is the possibility of investigating the effect of reducing the emissions of one compound on the emissions of the other compounds (i.e. pollution swapping).

Mechanically ventilated animal houses are characterised by well-defined air inlets and outlets (Figure 12).

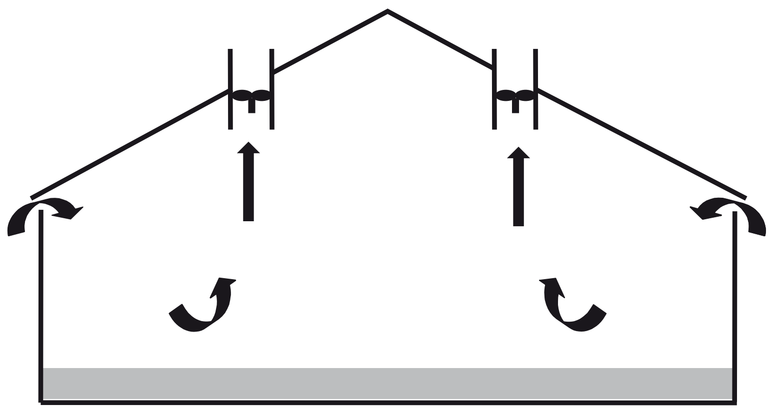

Figure 12: Schematic representation of the flow pattern for a particular mechanically ventilated animal house.

(Sections 7.3.4 and 7.4.2): Recommendations for tracer gas measurements (when measuring in naturally ventilated buildings)

- The horizontal position of the measurement points will depend upon the building design. For a symmetrical house, placing the measurement points in the middle of the house (Figure 13 A, position 1 or 2) is preferred. When measurement points are placed close to the side walls (Figure 13A, position 3), a minimum distance of two metres between the sampling point and the side wall should be used to minimise the effect of occasional interference of outside air on the sampling points inside the barn. For more open barns (e.g. open front, Figure 13B), the measurement points may be moved more in the direction of the outlet openings to allow for better dispersion of the air before being sampled. Care should be taken not to place the measurement points too close to the outlet openings (a minimum distance of two metres should be used). Smoke tests under different situations (curtain opening, wind speed and direction) may be helpful in defining the position of the measurement points.
- Regarding the vertical position of the sampling points, when cross ventilation is expected the recommendation is to measure in the middle of the barn at a height of at least three metres (Mendes et al., 2015) in order to minimise the effect of animals, cubicles and other obstacles (Figure 13A, position 2) instead of close to the ridge (Figure 13A, position 1). When air is expected to leave the barn through the ridge, moving the measurement points towards the ridge (at least two metres below the ridge to minimise the effects of outside air interference) is also a possibility, although measuring in the middle line remains possible.

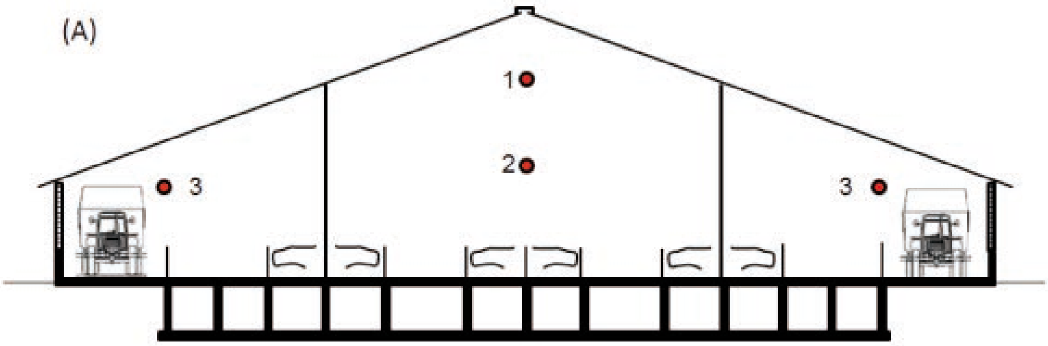

Figure 13: Positioning of measurement points inside a dairy barn. A) Symmetric design; B) Open front system.

- The number of measurement points to consider has not been investigated yet, although it is recommended to have at least one sampling point per ten metres of barn length (Figure 14). The sampling points should be provided with a critical orifice, to allow a constant and controlled sampling flow rate and a dust filter (Figure 15). The use of perforated tubes (with at least one hole every 10 m of sampling tube) is also permissible. Care should be taken that obstacles inside the animal house do not affect the representativeness of the measurement point (e.g. by changing flow patterns). If available, the use of open-path measurement equipment (measuring an average concentration over the whole length of the barn) is recommended.

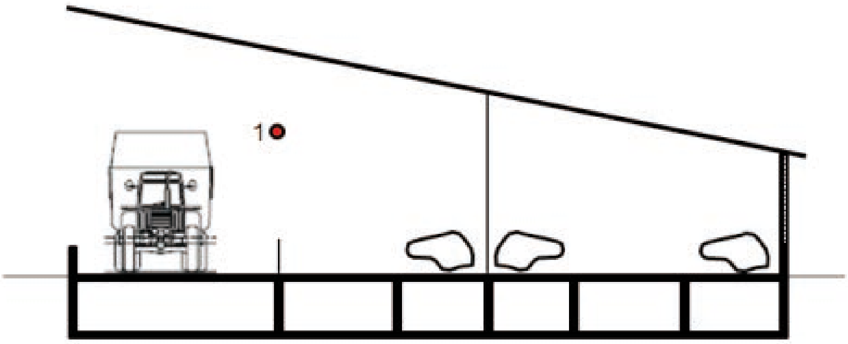

Figure 14: Schematic view of a dairy barn showing a distribution of sampling points (red dots) in the length of the barn.

Figure 15: left: Sampling point with critical orifice and dust filter. Right: Open-path laser system.

- Sampling points outside the house to measure the gas concentration of incoming air: (Note: term 'incoming air' preferred instead of 'background air' to distinguish the effects of nearby emission sources from 'clean' background). In general, placing a measurement point outside the barn at a distance of at least five metres from the barn (to minimise the effect of barn air on the outside air being sampled) may be enough to quantify the concentration of the measured gases (NH_3 and tracer gas) entering the barn if air is coming from non-polluted areas (e.g. Figure 16, position 1 for Southern winds). However, other sources in the proximity of the measured barn may increase the concentration of the air entering the barn, depending on the source location and wind direction. In these situations, the measurement strategy should be modified to include more measurement points in order to quantify the contribution of these sources (e.g. Figure 16, position 2 for northerly winds). Besides, a lower concentration difference between incoming and outgoing air is expected in the presence of other sources, which may require use of more accurate measuring equipment. When rapid changes in wind direction are expected, it is recommended (but not compulsory) to perform continuous measurements on both sides of the barn at the same time (at least five metres away from the building). The minimum concentration levels when comparing both sides will then specify the inlet concentration.

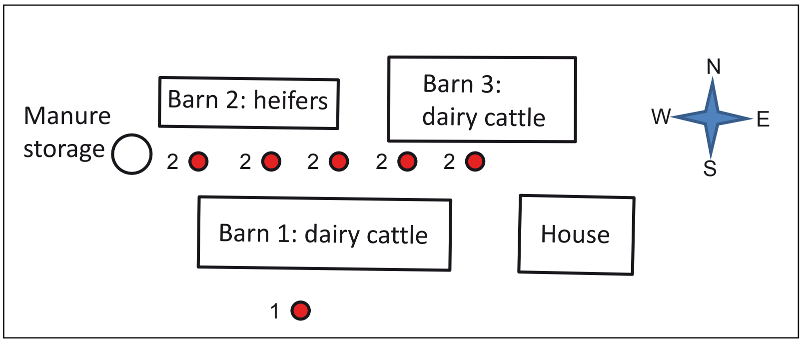

Figure 16: Positioning of measurement points for incoming air concentrations.

A minimum CO_2 concentration difference (outgoing–incoming air) of 200 ppm is not required, since skipping these measurements leads to a systematic underestimation of the ventilation rate and, consequently, of the respective emissions.

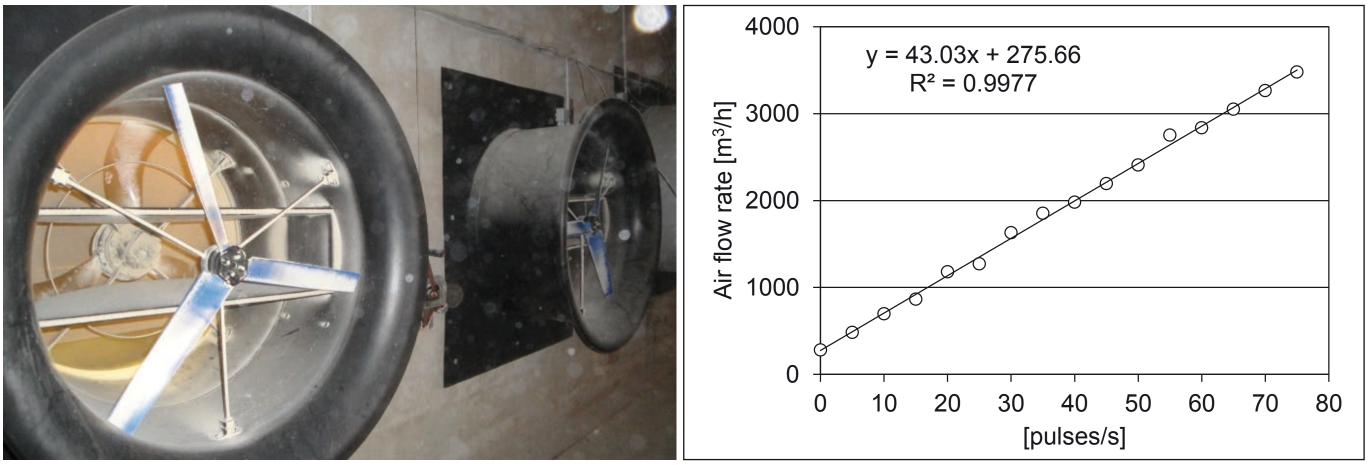

Figure 17: Fan-wheel anemometer (left) and calibration curve (right).

(Section 7.4.2): Fan-wheel anemometer

A fan-wheel anemometer gives a number of pulses per rotation. By registering the number of pulses per second and using a curve relating the ventilation rate to the anemometer response (number of pulses per second) the entire air volume leaving the animal house can be determined.

Fan-wheel anemometers are a robust method, providing accurate (± 5%, except for low air velocities) and direct measurements of air-flow rates. One of the limitations of using this method is that in order to measure the air-flow rate from mechanically ventilated livestock buildings, all ventilation shafts are to be provided with a calibrated fan-wheel anemometer.

(Section 7.4.2): Measurement of CO_2 contribution from litter

For farms with deep litter systems, measurement data on the CO_2 contribution by the bedding material must be presented. One way of doing this is by using closed flux chambers to measure the CO_2 production from the bedding at different places, and to take spatial variability in CO_2 production into account.

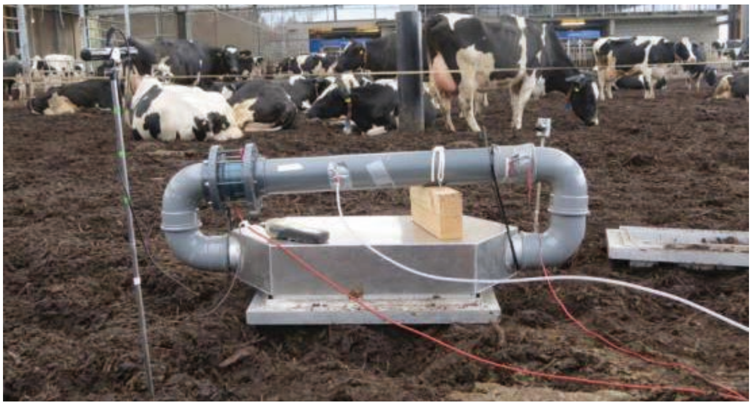

Figure 18: Closed flux chamber with air recirculation to measure the CO_2 production from bedding materials.

(Section 7.4.2.3): Artificial tracer gas method

The tracer gas constant injection method is the most commonly applied artificial tracer gas method. This approach (Figure 19) relies on initially charging the building envelope with tracer gas, and then setting an injection rate enough to produce an easily measurable concentration in the building (within the detection range of the measuring equipment). Monitoring the injection rate is generally accomplished by using a Mass Flow Controller (MFC). By recording the mass flow as a function of time, it is possible to calculate the total mass of tracer injected during a given time period. The tracer is mixed with compressed air at controlled mass flowrates before entering the building envelope to improve mixing of the tracer gas with air.

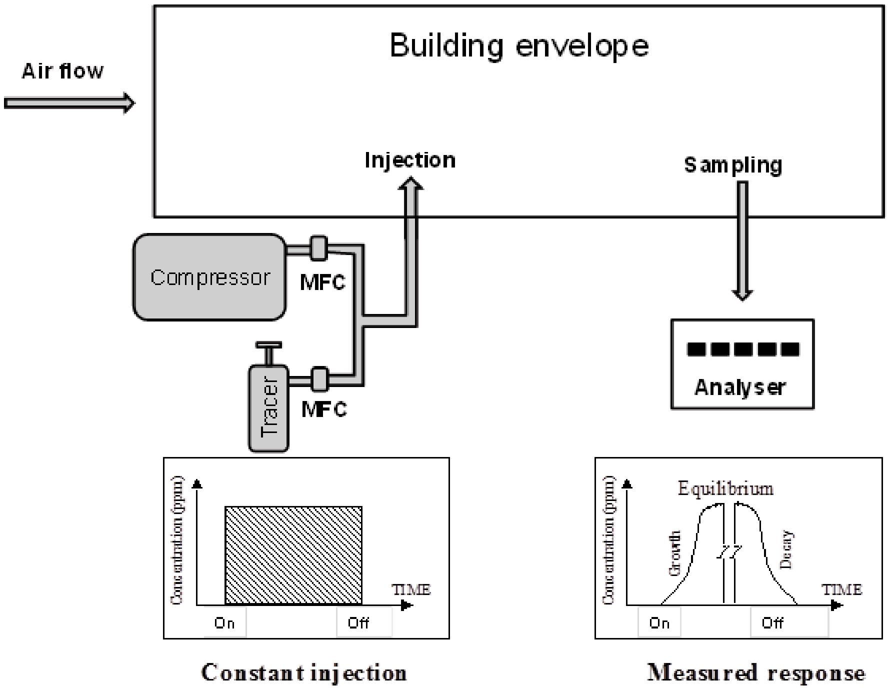

Figure 19: Schematic view of the tracer gas constant injection method.

Annex G (informative): Testing the gas recovery of the sampling system

As referred to in section 7.3.4, the recovery rate must be tested before starting the measurements.

The recovery of the gas of interest can be found using a certified gas with a concentration that is representative of the sampling points. To test long sampling lines with or without continuous flow, use one or two big (e.g. 60-litre) bags of an approved material for the gas of interest, with a concentration representative of the sampling points. The diluted gas can be created by using gases from a gas cylinder and a dilution system with pure air or nitrogen.

Measure the concentration of the bag with the inlet system of the instrument then place the bag on the sampling line and measure until a stable signal is achieved. Finally, repeat the measurement at the inlet of the instrument. The recovery is the ratio between the measured concentration in the bag at the sampling point and the instrument inlet.

Annex H (informative): CIGR calculation rules

The CIGR calculation rules are the basis for the calculating the emission values.

The metabolic CO_2 production is calculated using the equations and data in CIGR (2002) for heat production and subsequently the conversion of heat production into CO_2 production using the values in Table 6 in Pedersen et al. (2008).

The heat production (the unit is Heat Production Unit, HPU, which is 1000 W of total heat at 20°C) is based on the numbers and sizes of the animals, their production parameters (weight gain, milk or egg production, etc.), activity level and surrounding temperature based on equations from CIGR (2002). In some cases it may be necessary to extrapolate, e.g. for daily gain for fattening pigs. The extrapolation method should be described in the test report. Note that the heat production is based on daily means.

Since barn temperature (t_{barn}) normally differs from the standard indoor temperature (20°C), a temperature correction factor is applied to determine the CO_2 emissions from the animals.

The total CO_2 production from the animal and the manure system should be used for the trace gas ratio method. The CO_2 production from the manure system is incorporated in the column 'house level' in Table 6 in Petersen et al. (2008). However, for systems with deep litter, indoor manure storage, frequent flushing of slurry, reduced slurry surfaces, etc., the CO_2 production from the manure system should be measured, or artificial tracers should be used instead.

An Excel spreadsheet for calculation of emissions in dairy cattle is available on the VERA website and is recommended for the calculation of the CO_2 production.

The following standard values and equations are used in this spreadsheet:

	STANDARD VALUES			
Animal category	Weight m [kg]	Days in pregnancy p [d]	Energy value of feed M [MJ (kg dry matter)$^{-1}$]	Weight gain Y_2 [kg d^{-1}]
Milking cows	650	160	---	---
Dry cows	650	220	---	---
Heifers (pregnant)	400	140	10	0,6
Heifers (not pregnant)	250	---	10	0,6
Y_1: milk production [kg d^{-1}] --> measurements				

PCO_2 (milking cows) = $0.2*(5.6\ m^{0.75} + 22*Y_1 + 1.6*10^{-5}*p^3)/1000$

PCO_2 (dry cows) = $0.2*(5.6\ m^{0.75} + 1.6*10^{-5}*p^3)/1000$

$$PCO_2\ (\text{heifers, pregnant}) = 0.2*\left(7.64\ m^{0.69} + Y_2*\left(\frac{23}{M}-1\right)*\left(\frac{57.27+0.302*m}{1-0.171*Y_2}\right) + 1.6*10^{-5}*p^3\right)/1000$$

$$PCO_2\ (\text{heifers, not pregnant}) = 0.2*\left(7.64\ m^{0.69} + Y_2*\left(\frac{23}{M}-1\right)*\left(\frac{57.27+0.302*m}{1-0.171*Y_2}\right)\right)/1000$$

PC: CO_2 production per heat production unit (HPU), expressed as $m^3\ CO_2\ h^{-1}$ per HPU
- PC = 0.18 for closed floors
  (no contribution of manure in manure pit to CO_2 production in livestock building)
- PC = 0.20 for (partly) slatted floors
  (includes 10% contribution of manure in manure pit to CO_2 production in livestock building)

PCO_2 = PCO_2 (milking cows) * number of milking cows
+ PCO_2 (dry cows) * number of dry cows
+ PCO_2 (heifers, pregnant) * number of pregnant heifers
+ PCO_2 (heifers, not pregnant) * number of not pregnant heifers

$PCO_2 = PCO_2*(1000 + 4*(20 - t_{inside}))/1000$

t_{inside}: temperature [°C] inside the barn

Emissions (E_i; kg $year^{-1}\ AP^{-1}$) are calculated per measurement day using PCO_2 ($m^3\ CO_2\ h^{-1}$), and the average concentrations (24 hours, in mg m^{-3}) of NH_3 and CO_2 inside and outside the building according to

$$E_i = PCO_{2i}*\frac{(NH_3)_i^{inside}-(NH_3)_i^{outside}}{(CO_2)_i^{inside}-(CO_2)_i^{outside}}*\frac{1\ kg}{10^6\ mg}*\frac{24\ h}{1\ d}*\frac{365\ d}{1\ a}*\frac{1}{AP}$$

Annex I (informative): Ammonia emission factors for different animal categories

The table below shows ammonia emission coefficients and emission factors for different livestock categories and housing systems in Germany (DE), the Netherlands (NL) and Denmark (DK).

Table 14: Ammonia emission factors.

Livestock	Housing and floor system	Manure[a]	DE (kg NH_3-N kg^{-1} N[b])	DE (kg NH_3 AP^{-1} $year^{-1}$)[c]	NL (kg NH_3 AP^{-1} $year^{-1}$)[d]	DK (kg NH_3-N kg^{-1} TAN)[b]	DK (kg NH_3-N kg^{-1} N[g])
Dairy cows	Cubicle house (solid or slatted floor (channel, back flushing)), no grazing	Liquid	0.236	14.6	-	0.16	
	Solid drained floor	Liquid		-	-	0.08	
	Deep litter	Deep litter	0.236	14.6	-		0.06
	Zero grazing, slatted floor	Liquid			13		
Grower/ finishers	Partially slatted (solid 50-75%)	Liquid	0.268	3.6	3.0	0.13	
	Partially slatted (solid 25-49%)	Liquid		3.6	-	0.17	
	Fully slatted floor (1/3 of the space requirement max 10% opening area)					0.21	
	Fully slatted	Liquid	0.268	3.6	4.5	0.24	
	Deep litter	Deep litter	0.384	4.9	-		0.25
Weaners	Two-climate housing, partially slatted	Liquid	0.196[e]	0.4	0.39	0.10	
	Fully slatted	Liquid	0.268	0.5	0.69	0.24	
	Deep litter	Deep litter	0.384		-		0.15
Sows, pregnant	Individual, partially slatted	Liquid	0.239[f]	7.3[h]	4.2	0.13	
	Individual, fully slatted	Liquid			-	0.19	
	Group, partially slatted					0.16	
	Group, deep litter	Deep litter			2.6		0.15
Sows, lactating	Box, partially slatted	Liquid			8.3	0.13	
	Box, fully slatted	Liquid			-	0.26	
Broilers	Deep litter	Deep litter	0.138[g]	0.05	0.068		0.20
Layers	Free-range, solid manure	Solid	0.351[g]	0.32 floor housing, manure pit	0.315		0.32
	Enriched cage, belt removal	Solid					0.12
	Aviary, belt removal	Solid					0.14
	Deep litter system	Solid					0.36

a Liquid manure: Based on TAN = total ammoniacal nitrogen (nitrogen in urine)
Deep litter and solid manure: Based on total nitrogen excreted in urine and faeces.
b Related to TAN.
c AP = the number of permitted animals
d For NL only reference housing systems included; minimum levels for BAT-systems are lower.
e Naturally ventilated housing with kennels.
f No differentiation between the housing systems.
g Related to total N.
h for all stages; sows, pregnant: 4.8, sows, lactating: 8.3

Comments:
Weaners, fully slatted: Two types predominate in DK: 'two-climate housing, partially slatted' and '50% drained floor/50% slatted floor'.

Layers, free-range, solid manure: In DK it is assumed that 10% of total N ex-animal is excreted outside the house, 30% of N is excreted in the deep litter inside the house, and the remaining 60% of N is excreted on the slats. 25% of N excreted in the deep litter area is lost as ammonia, whereas 40% of N excreted on the slats is lost as ammonia. Thus. overall ammonia-N emissions are (0.30*0.25+0.60*0.40) = 0.32 kg NH_3-N per kg N excreted. The 10% of manure-N which is excreted outside the house is not accounted for.

Layers, aviary, belt removal: In DK it is assumed that 75% of total N ex-animal is excreted on the manure belts and the remaining 25% is excreted in the deep litter.
10% of N excreted on the manure belts is lost as NH_3-N, and 25% of N excreted in the deep litter area is lost as NH_3-N. Thus, the average ammonia-N emissions are (0.75*0.10+0.25*0.25) = 0.14 kg NH_3-N per kg N excreted.

Layers, deep litter, solid manure: In DK it is assumed that 33% of N is excreted in the deep litter inside the house, and the remaining 67% of N is excreted on the slats. 25% of N excreted in the deep litter area is lost as ammonia, whereas 40% of N excreted on the slats is lost as ammonia. Thus the average ammonia-N emissions are (0.33*0.25+0.67*0.40) = 0.36 kg NH_3-N per kg N excreted.

Relating measured ammonia emissions to nitrogen ex-animal (DK approach)

In the Danish normative system, ex-animal calculation of norm values is performed as a simple difference between nitrogen input and output. Input is based on recordings and calculations of feed intake for the different livestock categories, combined with statistics on nutrient concentrations in the diet. Thereafter, the nutrient retention in the animal products (meat, milk and eggs) is calculated based on standard values, and subtracted. The separate excretion of nutrients into faecal and urinary fractions is also calculated using digestibility coefficients for the different nutrients (Poulsen et al., 2001, 2006).

The norm values, including ex-animal nitrogen, are calculated annually. For each animal category, the norm values apply to a certain feed intake, weight range (i.e. meat production), milk production, and/or egg production. If basic parameters obtained during a test differ from the values outlined in the published norm values in the relevant year, Poulsen et al. (2001) prescribe animal-specific equations to recalculate the nitrogen ex-animal values.

References:
German data: Dämmgen, U. (ed.) (2009) Calculation of emissions from German agriculture – National emission inventory report (NIR), vTI Agriculture and Forestry Research, special issue 324.
VDI Guideline VDI 3894, Blatt 1 (2011): Emissions and immissions from animal husbandry – Housing systems and emissions – Pigs, cattle, poultry, horses. Beuth Verlag, Berlin

Dutch data: Infomil, (2009). Information centre for the environment: Infomil. Regulatory list of ammonia emission factors and system description, in Dutch. Available at: http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak/rav/stalbeschrijvingen/

Danish data: Poulsen, H. D., Børsting, C. F., Rom, H. B., and Sommer S. G. (Eds.), (2001). Kvælstof, fosfor og kalium I husdyrgødning – normtal 2000 (Nitrogen, phosphorus and potassium in livestock manure – norm figures 2000). DJF Rapport nr. 36 Husdyrbrug, Ministeriet for Fødevarer, Landbrug og Fiskeri, Danmarks JordbrugsForskning. pp. 152. http://web.agrsci.dk/djfpublikation/djfpdf/djfhd36.pdf

A condensed description is provided by Poulsen et al. (2006). Quantification of nitrogen, phosphorus in manure in the Danish Normative System. In: Petersen, S.O. (Ed.). 2006. Technology for Recycling of Manure and Organic Residues in a Whole-Farm Perspective. 12th Ramiran International conference. Vol. II, DIAS report no. 123. Ministry of Foods, Agriculture, and Fisheries, Danish Agricultural Sciences, pp. 105-107.

Annex J (informative): Odour emission factors for different animal categories

The table below shows odour emission coefficients for different livestock categories and housing systems in Germany (DE), the Netherlands (NL) and Denmark (DK).

Table 15: Odour emission factors from production units with pigs.

Animal type	Housing unit	DE [OU_E LU^{-1} s^{-1}] annual average	NL [OU_E AP^{-1} s^{-1}]	DK (5th & 95th percentiles)
Dry sows	Sows kept in individual crates	22	19	16 OU_E s^{-1} $animal^{-1}$ (7-39)
	Sows kept loose	22	19	16 OU_E s^{-1} $animal^{-1}$ (7-39)
Lactating sows	Sows and piglets kept in crates with partially slatted floors	20	28	72 OU_E s^{-1} sow^{-1} (40-125)
	Sows and piglets kept in crates with fully slatted floors	20	28	100 OU_E s^{-1} sow^{-1} (56-280)
Weaners	Weaners kept in pens with partially slatted floors	75	8	380 OU_E s^{-1} $(1000\ kg\ animal)^{-1}$ (200-750)
	Weaners kept in pens with fully slatted floors	75	8	380 OU_E s^{-1} $(1000\ kg\ animal)^{-1}$ (200-750)
Finishers	Finishers kept in pens with partially slatted floors	50	23	300 OU_E s^{-1} $(1000\ kg\ animal)^{-1}$ (110-810)
	Finishers kept in pens with fully slatted floors	50	23	450 OU_E s^{-1} $(1000\ kg\ animal)^{-1}$ (190-1200)

Table 16: Odour emission factors from production units with cattle.

Animal type	Housing unit	DE [OU_E LU^{-1} s^{-1}] annual average	NL [OU_E AP^{-1} s^{-1}]	DK
	All types of housing units	12		170 OU_E s^{-1} $(1000\ kg\ animal)^{-1}$
Beef cattle 6–24 months old		12	36	
Veal calves		30	36	

Table 17: Odour emission factors from poultry.

Animal type	Housing unit	DE [OU_E LU^{-1} s^{-1}] annual average	NL [OU_E AP^{-1} s^{-1}]	DK [OU_E s^{-1} (1000 kg animal)$^{-1}$]
Layers	Floor systems	42	0.35	900
Layers	Cages	30 small group housing systems (furnished cages)	0.34	400
	Aviary system	30	0.34	
			0.34	
Broilers	Deep litter	60	0.33	400

Sources:

Dutch data: Infomil, 2009. Information centre for the environment: Infomil. Regulatory list of ammonia emission factors and system description, in Dutch. Available at:
http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak/rav/stalbeschrijvingen/

German data: VDI Guideline VDI 3894, Blatt 1 (2011): Emissions and immissions from animal husbandry – Housing systems and emissions – Pigs, cattle, poultry, horses. Beuth Verlag, Berlin

Annex K (informative): Dust (PM10) emission factors for different animal categories

The table below shows dust emission factors (PM10) for different livestock categories and housing systems in Germany (DE), the Netherlands (NL) and Denmark (DK).

Table 18: Dust (PM10) emission factors.

Livestock	Housing and floor system	Manure	DE [kg AP^{-1} a^{-1}]	NL [kg AP^{-1} a^{-1}]	DK (Not available)
Dairy cows	Slatted (channel, back flushing)	Liquid	0.18	0.148	
	Deep litter	Deep litter	0.4	-	
Grower/ Finishers	Partially slatted (solid 50–75%)	Liquid	0.24	0.153	
	Partially slatted (solid 25–49%)	Liquid		-	
	Fully slatted	Liquid	0.24	0.153	
	Deep litter	Deep litter	0.32	-	
Piglets	Two-climate housing, partially slatted	Liquid	0.08	0.074	
	Fully slatted	Liquid	0.08	0.074	
	Deep litter	Deep litter	-	-	
Sows, pregnant	Individual, partially slatted	Liquid	0.16*)	0.175	
	Individual, fully slatted	Liquid	0.16*)	0.175	
	Deep litter	Deep litter	0.8*)	-	
Sows, lactating	Box, partially slatted	Liquid	0.16*)	0.160	
	Box, fully slatted	Liquid	0.16*)	-	
Broilers	Deep litter	Deep litter	0.015	0.022	
Layers	Free-range, solid manure	Solid manure	0.12	0.084	

*) For all stages

Sources:

Dutch data: Infomil, 2009. Information centre for the environment: Infomil. Regulatory list of ammonia emission factors and system description, in Dutch. Available at:
http://www.infomil.nl/onderwerpen/landbouw-tuinbouw/ammoniak/rav/stalbeschrijvingen/

German data: VDI Guideline VDI 3894, Blatt 1 (2011): Emissions and immissions from animal husbandry – Housing systems and emissions – Pigs, cattle, poultry, horses. Beuth Verlag, Berlin

Annex L (informative): Template for a test plan

NAME OF TEST INSTITUTE

TEST PLAN FOR [name of slurry separation technology]

delivered from [name of manufacturer/applicant]

CONTACT DATA

Type of technology	
Name and address of manufacturer/ applicant	
Facility owner Name and address	
Address of housing unit (if different from address of the herd owner)	
Health status	
Visiting rules	
Start of test (dd/mm/yy)	
End of test (dd/mm/yy)	
Name and address of test institute	
Technician responsible	
Technician(s)	
Consultant(s) from the test institute	
Local advisor/veterinarian	
Contact person from the company financing the test	
Service technician(s) from the supplier of the technology/system	
File	

BACKGROUND AND AIM [maximum of one page]
A short description of the system and a reference to where details can be found should be included. The development process of the system and any previous tests must be specified (all references must be included in the reference list at the end of the test plan).

The section must include a precise description of the aim of the test and a specification of the test parameters.

TEST PROCEDURE
The description of the test procedure must include the following items:

- Description of the herd and the housing system/technology where the test is to be carried out. Previous descriptions of the individual components in the system/technology must be specified in an appendix to the test plan. The verification body can then check that the system/technology applied is identical to the tested system/technology.
- Specification of the primary measurement parameters, e.g. odour, ammonia and dust (VERA test protocol, Table 4).
- Specification of the secondary measurement parameters (VERA test protocol, Tables 5 to 7).
- Description of the location of measurement points, instruments, and how they are calibrated.
- Description of the work procedures in the housing unit and how the animal production parameters should be recorded.
- Timetable for the entire test period.
- Logbook. Location of logbook and description of parameters to be recorded.

DATA RECORDING
The tables provided for recording data must be presented.

ALLOCATION OF RESPONSIBILITY
The allocation of responsibility must cover all working processes in the system/technology so that the technician can use the list when instructing the stockmen.

A list must be drawn up for each section and system/technology.

What needs to be done	When	By whom

PROCESSING OF RESULTS
Raw data must be presented in tables, which must be included as appendices to the final test report. The raw data must also be presented in graphs, which must be included in the results section in the final test report.

The primary measurement parameters must then be analysed in accordance with the specifications given in the test protocol. *For example, the ammonia concentration and the logarithmically transformed odour concentration can be processed with an analysis of variance in the MIXED Procedure in SAS (SAS Inst. Inc., Cary, NC).*

Both the median and the 95th percentiles must be calculated for odour concentration and odour emissions. For the other primary parameters, the mean must be calculated instead of the median.

The mean and standard deviation must be calculated for the secondary parameters according to the test protocol.

COMPENSATION
Any arrangements made in relation to providing the owner of the test location with financial compensation in connection with the test may be described, e.g. farmer paid DKK/Euro XXX per hour for any extra work.

APPENDICES

The appendices may include all data recording tables, e.g. tables of:

- Odour recordings
- Ammonia recordings
- Defecation behaviour
- Production data.

UPDATES TO THE TEST PLAN

The test plan must be updated every time changes are made. It is not sufficient to list the changes in the logbook. For each update, the date for the changes must be noted, and the test plan must be assigned a new version number.

Example:

1st version: DD/MM/YY Initials 1 / Initials 2
2nd version: DD/MM/YY Initials 1 / Initials 2

It is recommended to have the test plan approved by the verification body prior to the initiation of a VERA test.