Technical Manual on Respiration Chamber Designs

February 2014

Edited by Cesar Pinares and Garry Waghorn

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Ministry of Agriculture and Forestry
Pastoral House, 25 The Terrace
PO Box 2526, Wellington 6140, New Zealand
Tel: +64 4 894 0100 or 0800 00 83 33
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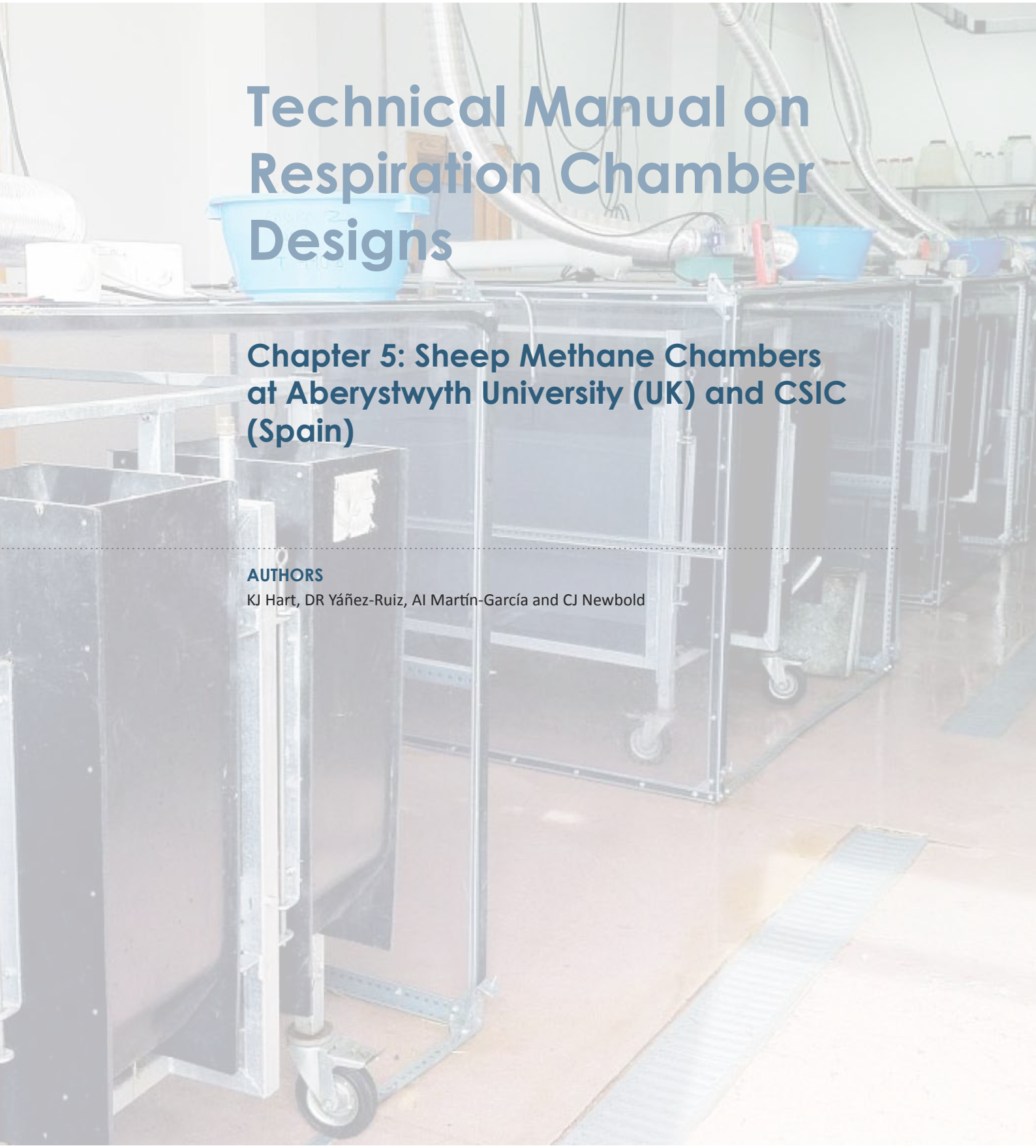

Technical Manual on Respiration Chamber Designs

Chapter 5: Sheep Methane Chambers at Aberystwyth University (UK) and CSIC (Spain)

AUTHORS
KJ Hart, DR Yáñez-Ruiz, AI Martín-García and CJ Newbold

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5.1 Summary

Four open circuit respiration chambers have been constructed to quantify sheep methane production. There is no intention to determine energetics. The chambers are of approximately 5 m^3 internal volume with an air flow rate of 2 m^3/min and consist of a polycarbonate (4 mm) shell affixed to a powder coated steel frame (25 × 25 mm box section; 1.80 × 1.80 × 1.53 m) with 90 × 90 mm steel mesh lining the sides. The front of each chamber has 2 doors where there is an air gap of 33 cm not covered by polycarbonate along the width of the front. The chambers are sited on a concrete floor that is covered by a 12 mm rubber mat. Waste is removed by daily scrapping through the door. Chamber airflow is measured twice daily by a hotwire flow meter. A continuous subsample of gas (1 L/min) is drawn from the air exhaust and ambient air supply, through a moisture trap (silica) into a gas analyser (MGA3000; ADC analyzers) with an integral 8 channel multiplexor. Methane concentrations are measured every 60 seconds for 5 minutes from each channel. Gas concentrations and air flow measurements are loaded into an Excel spreadsheet for each chamber allowing methane measurements every 30 minutes. Methane recovery through chambers is measured by injection of a known dose of methane over a 24 h period prior to each experimental run.

A set of four open circuit respiration chambers for sheep and goats have been constructed at CSIC (Spain) based on the Aberystwyth's design, with slight modifications.

5.2 Location of the facility

The physical address of the facility is:

Aberystwyth University
Gogerddan Campus
Aberystwyth
Ceredigion
SY23 3DA
Wales

Consejo Superior Investigacion Cientifica (CSIC)
Camino del Jueves s/n
E-18100 Granada
Spain
Phone: + 34 958 572 757
Fax: + 34 958 572 753

Contact persons:

1 Contact at IBERS
Prof. CJ Newbold
Phone: + 44 1970 622242
Email: cjn@aber.ac.uk

2 Contact person at CSIC (Spain)
Dr. A Ignacio Martín-García
Phone: + 34 958 572 757 (ext. 353)
Fax: + 34 958 572 753
Email: imartin@eez.csic.es

The chambers are located in an enclosed barn in Aberystwyth in Wales, United Kingdom at 31 m altitude. This is on the University of Aberystwyth's Gogerddan Campus and is within 100 m of the main sheep housing and handling facilities. The location is situated away from public rights of way. Limited penning of 20 sheep exists within the barn to facilitate moving blocks of sheep in and out of the chambers. If required, animals are transported to and from the facility in a trailer towed by an ATV. The barn is constructed of blocks with slatted wood ventilation and the front of the building has a large roller door to allow vehicular access. The barn is not insulated and not heated and runs at ambient pressure and temperature. A mobile sheep weigh crate is located within the building to weigh the sheep before and after each methane run. Rumen fluid and blood samples can be taken whilst the sheep are manually restrained in their individual pens or within the handling system of the main sheep housing in accordance to the Animals (Scientific Procedures) Act 1986.

The chambers in Spain are located in Granada at the Institute of Animal Nutrition from the Spanish Research Council (CSIC) at 723 m altitude. The facilities include a barn that can hold 55 sheep or goats and an animal trial building housing the chambers. The facility is part of research Institute devoted to Animal Nutrition studies employing around 40 personnel. Within the animal trial building, there are two rooms (65 m^2 each) connected through a corridor with positive air pressure to avoid air cross-contamination between them. One room is used for the adaptation of the animals to the cages and the other where the set of chambers is placed. Both rooms are air-conditioned to maintain the temperature about 25 ^oC (±5 ^oC). An adjacent third room houses instrumentation for sampling, instrument calibration, measuring and data processing.

5.3 Chamber airflow piping and measurement

The four chambers at Aberystwyth are arranged in 2 rows of 2, with the chamber doors opening onto a common aisle that runs between the 2 rows (Plate 1). The chambers are constructed of 25 mm × 25 mm powder coated steel box section modular frames to give length, width and height of approximately 1.80 × 1.80 × 1.53 m and an approximate volume of 5 m^3. The panels consist of a roof, 3 sides and a bisectional front door. To the internal frame a 90 mm × 90 mm steel mesh was welded to protect the exterior polycarbonate sheeting from being damaged. The bottom of the 3 sides had a 330 mm high section of stainless steel sheet welded to them in order to facilitate cleaning. Polycarbonate (4 mm) sheeting is attached to the external frame using foam pads and tech screws in order to completely cover the 3 sides and roof. However, at the bottom of the 2 doors had an air gap of 33 cm left in order to allow air entry to the chamber (Plate 3). The air gap also facilitates as a safety mechanism in case of power failure to the fans. Each panel was bolted together and joints sealed with silicone. The front doors of the chamber are half width and have a baton running from the top to the bottom to allow the doors to be fastened securely once the sheep is inside. Feed and water are manually placed within each chamber in buckets.

Chambers at CSIC are arranged in a single row (Plate 2) and have a single front door that can be dismantled and closed mounting it on two bolts at the bottom and secured by means of two springs in the upper part (Plate 4)

5.4 Animal holding, feeding and cleaning

At Aberystwyth, the animals to be measured for methane production are adapted to diet for at least 21 d in individual pens in the main sheep housing and are fed a diet at 1.05 x maintenance requirements (AFRC, 1993). Sheep are blocked in groups of four according to live

Plate 1: Aberystwyth University sheep respiration chamber facility showing the 4 chambers.

Plate 2: CSIC sheep and goats respiration facility composed of chambers and crates to hold the animals.

Plate 3: Front chambers at Aberystwyth University showing the gap at the bottom of the door to allow air to flow in.

Plate 4: Front of two chambers at CSIC Granada showing the gap at the bottom of the door to allow air to flow in.

Plate 5: Mobile crates at CSIC to hold the animals during adaptation and in the respiration chamber.

weight, age and gender. Animals are bedded on sawdust and have *ad libitum* access to water at all times. Animals are fed in 2 equal portions at 09:00 and 16:00 h daily with refusals being recorded each morning. The feed intake of each block of sheep is averaged for the 7 days preceding entry into the chambers and this amount used to feed each sheep within the block whilst within the chambers. Sheep are moved into the chambers prior to the morning feed and remain resident within the chambers for three 24-h periods. Whilst within the chambers a fine sprinkling of sawdust is placed upon the mats to soak up urine and this is replenished twice a day following manual scrapping of the chamber area. Once the sheep have been removed they are sampled as required and then the mats are scrapped and hosed down and allowed to dry for 24 h prior to the next block of sheep. The chambers are permanently affixed to the floor. Wash water and waste material is directed to a sunken drain covered with a grill that drains away outside the shed.

At CSIC, the sheep are placed in crates (1.0 m wide, 1.5 m long and 1.3 m high) (Plate 5), which are wheeled into the respiration chambers. The crates are made of the same components as the pens in the barn to help animal acclimatisation. Normally, animals start the acclimatisation period to the experimental treatment in the stable and are moved on day 14 to the crates in the acclimatisation room where they stay for at least a week. Then, they are moved into the chambers for gas measurements over three 24-h periods. Keeping the animals in the same crates during adaptation and measuring periods has been proven to prevent animals' distress and potential drop in dry matter intake. Collection trays for feed refusals collection that are disposed at the front of the crate allows for accurate measurement of daily feed intakes.

5.5 Chamber airflow piping and measurement

The respiration chamber air flow is reliant upon negative pressure in the system, achieved by high speed, in line fans placed at the exhaust of each chamber. A common stream of ambient air is drawn from the common aisle between the chambers within the shed through the open section of the front doors. The air is naturally circulated within each chamber and exhausts through a 10 cm diameter outlet hole in the centre of the roof section at the opposite end to the doors. Air passes through a 50 cm length of flexible 10 cm diameter plastic hose into

Plate 6: Top of the chamber at Aberystwyth University showing hand held flow meter inserted into the exhaust pipe.

an inline fan and the air exiting the fan is connected to a 120 cm length of the same flexible pipe which joins onto a 360 cm length of 10 cm diameter rigid pipe containing two 90 degree bends prior to being vented to the outside of the shed through plastic 10 cm diameter tubing. Within the first section of rigid pipe that runs across the front of the chamber is a 2.5 cm hole drilled, approximately half way down the length of pipe, which allows insertion of the hot wire anemometer (Plate 6), when not in use a rubber bung is inserted. A subsample of exhaust gas is continually withdrawn from half way down the sections of straight pipe through a 6 mm diameter plastic pipe. Four similar lines are located within the common aisle to sample the ambient air. A variable speed fan controller (Plate 8) is fixed to the top of each chamber in order to regulate air flow for the readings of exhaust gas to be less than the maximum range of the analyser.

At CSIC Granada, exhausting pipes are made of aluminium and contain three 90 degree bends prior to being vented. Air flow out of the chambers is measured using a 50 cm length tube inserted after the ventilation fan and connected to a flow-meter that contains a dynamic differential-pressure sensor and an electronic measuring and control unit (VAV-Universal VRD2, Belimo Automation AG, Brunnenbachstrasse, Switzerland) (Plate 7).

5.6 Sampling, sample conditioning and analysis

Each of the 8 sample lines (1 L/min) are connected to an individual channel of the gas analyser. Prior to the analyser, each sample line passes through a desiccant (silica) and then a membrane filter to remove any particulates that would affect the analyser. When the solenoid for a chamber (or the ambient line) is open, dried air from that sample line is directed internally to the analyser.

The analyser itself is an ADC MGA3000 (Plate 9) fitted with an infrared detector for methane (50 or 200 ppm) (CSIC: 300 and 1,000 ppm respectively for CH_4 and CO_2). Every 4 h the analyser auto zeros on oxygen free nitrogen. Calibration of the analyser is completed daily using a 50 ppm (Aberystwyth, UK) or 240 ppm (CSIC, Spain) span gas following a manual zeroing both calibration gases being dispensed at 5 psi from the cylinder into the back of the analyser.

5.7 Gas recovery test

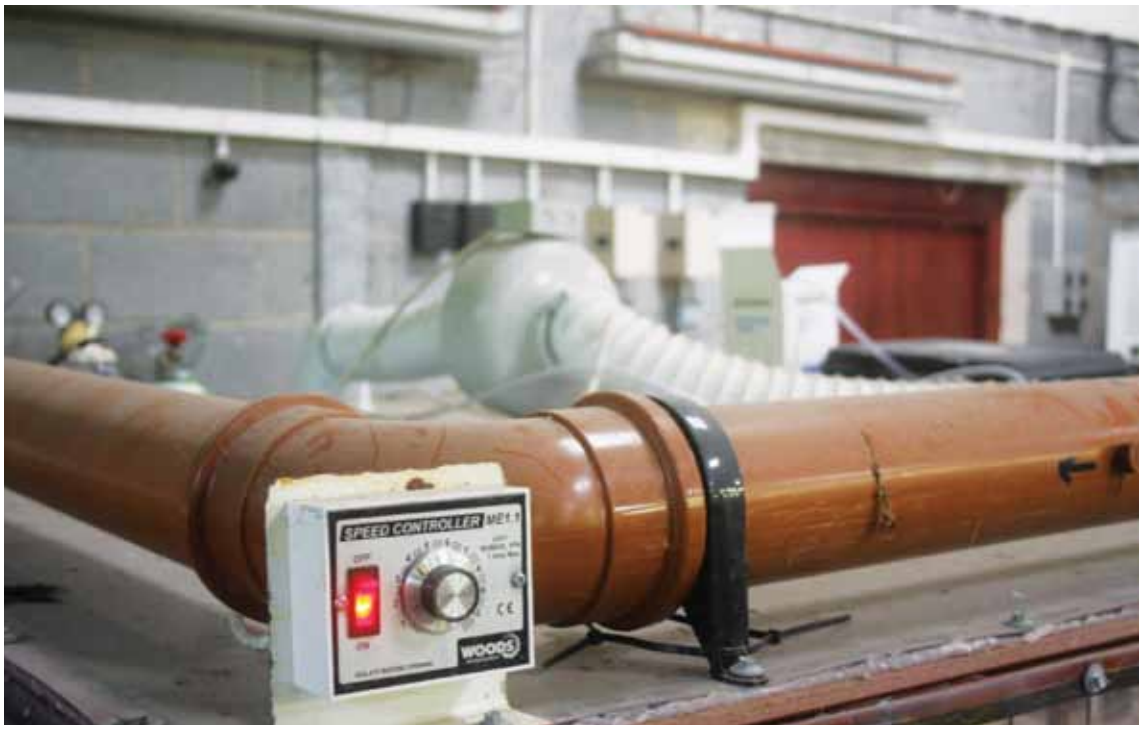
Recovery of methane through the chamber is quantified over a 24 h period. A bag containing a known volume and concentration of methane is connected to a multichannel pump dispenser to which is also connected a reservoir of water that is pumped at the same rate into a measuring cylinder. The gas is piped into the chamber through the front air grill and normal measurement cycles are followed. Following the 24 h the recovery of the gas is calculated and if it falls between 98–102% the chambers are ready for use. If the recovery is <98% all components are checked and the test re-run and if recovery is > 102% the analyser is recalibrated and verified against the span gas prior to rerunning the test for a further 24 h.

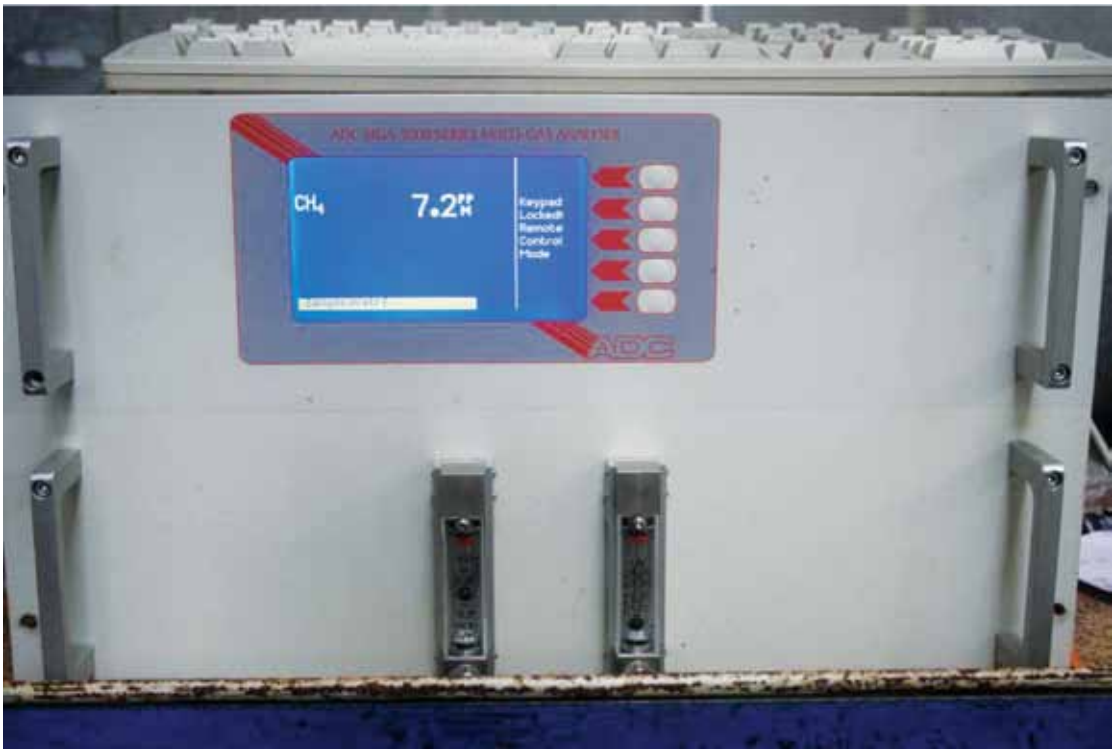
5.8 Emissions calculation

Average methane concentrations are determined for each chamber and ambient line within an Excel spreadsheet. Air flow is calculated from the 2 mean airflow readings from the anemometer which has been pre-set to calculate air volume from air velocity measurements assuming an internal pipe diameter of 100 mm. The mean methane concentration from each chamber is corrected for mean ambient methane concentration and total methane emissions are calculated based on the total air volume. Methane production is calculated as g/d.

Plate 7: Top of the chamber at CSIC showing the flow meter and electronic measuring unit.

Plate 8: The variable fan speed controller and the inline fan positioned on the top of each chamber, at Aberystwyth University.





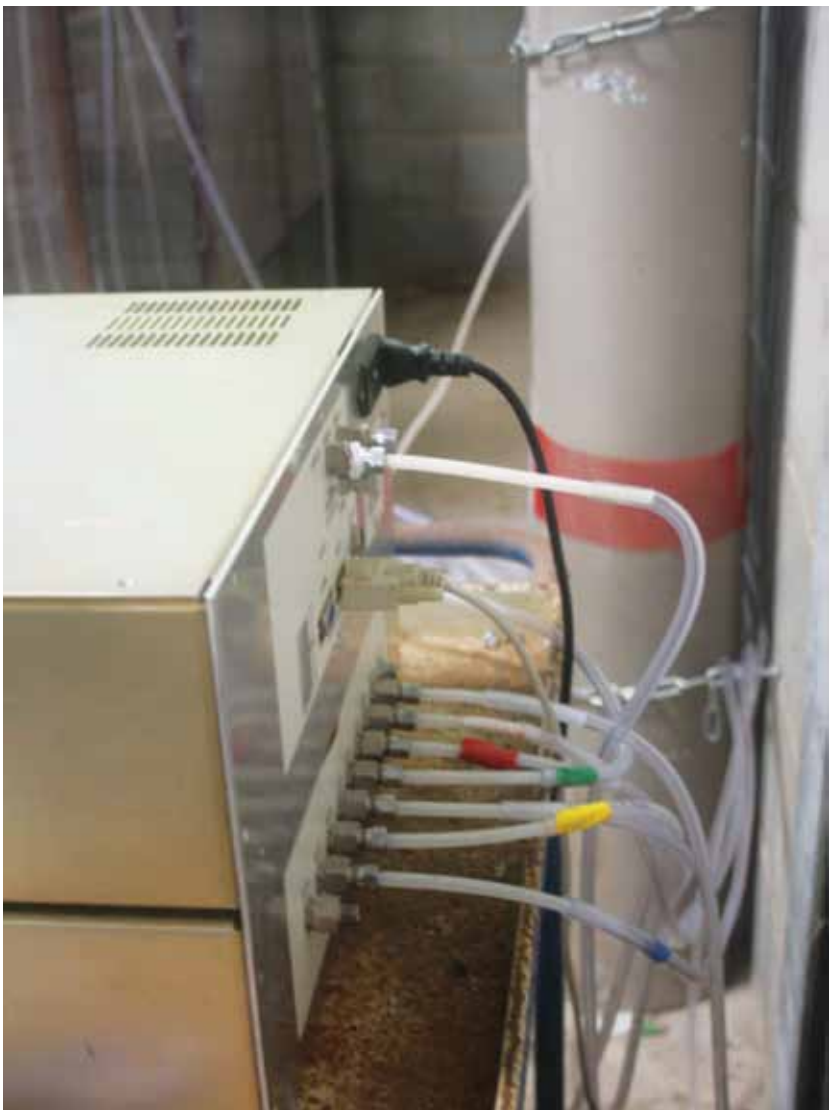


Plate 9: Gas analyser used by both Aberystwyth University and CSIC which includes an integral switching unit (lower photo).

Feed intake and DM content are recorded daily to enable emission to be reported as g methane and g methane/kg DM intake.

5.9 Animal welfare and operators' safety

Operator safety

The chambers are designed to allow sheep to be guided into them. Two handlers are always present when moving sheep in and out of the chambers. This is achieved by:

- A race of hurdles is constructed allowing easy movement of the sheep from the pens or loading bay.
- For getting animals into chambers, one side of the chamber door (framed polycarbonate) is opened only allowing the animal into the correct chamber or return the way it has come. The animals are followed by the operators in order to prevent them from returning. The door is sealed manually and locked using a fold-over catch.
- The door on the opposite chamber is then opened and that chamber filled in like manner.

Animal welfare

There is a small risk of asphyxiation which may occur in the event that air flow through the chambers is stopped (power blackout or fan fault). However, this is unlikely due to the air gap which allows air entry into each chamber. The analyser and computer are connected to a UPS which enables the system to carry on logging following resumption of power to the fans. At CSIC air velocity is always set to allow a maximum CO_2 concentration threshold in chambers around 1200 ppm.

5.10 Weaknesses of the system

The system at Aberystwyth was one of the first to be constructed and therefore has some notable problems that when finances allow will be retrofitted. Key improvements anticipated are:

- The air flow is only recorded twice daily, however ,10 readings are taken at each time point from each chamber in order to get an accurate representation of the air flow. Constant monitoring every 30 min of a single chamber, containing a sheep, demonstrated little change in an 8 h day. There is potential of inaccurate readings due to the necessity of the hot wire to be perpendicular to the air flow which cannot be seen once the probe is located within the pipe.
- The number of readings recorded is 10 readings per chamber per hour; this is predetermined by the analyser. This does not allow for flux measurements to be recorded over a short period.
- While functional, the data collection and processing software still requires considerable manual processing. We hope to get this automated quickly and will work with the designer to do so.
- It is anticipated that a cylinder of known methane concentration could be connected to a channel on the analyser. However, a way needs to be designed to allow gas to flow out of a high pressure cylinder at 1 L/min in order that the cylinder does not empty in a short time period.
- At CSIC Granada, signal from dynamic differential-pressure sensor (0 to 10 V) is manually recorded (4 times/day) from the connected potentiometer. There is a good linear correlation within these values and those from an anemometer (m/s) fitted in the centre

of the exhaust pipe. Despite the stability of air flux produced by the fan, automatic continuous record of measurements in the lab computer via the suitable data-logger should increase the accuracy of CH_4 emission measurements.

5.11 Description of components and equipment suppliers

Chamber design and construction:	Local contractor
Air ducting system and fans:	Flakt Woods and local builders merchants
Gas analyser and switching unit:	ADC Gas analysis, UK
Mass flow:	TSI Airflow instruments VAV-Universal VRD2, Switzerland (CSIC)
Data handling software:	Microsoft Excel

5.12 Costing of the facility

ITEMS	US$
LABOUR AND MATERIALS	
Design of the system	In house
Building of chambers	7,500
Piping air circulation and sample lines	700
Mobile animal crates	6,600 (CSIC only)
EQUIPMENT	
Air flow meter	1,800[1]
Gas analyser[2], inc switching unit	11,500 (CH_4)
Calibration gases	600
Analyzer control software	2,990
Computer and data acquisition system	1,000
TOTAL COST	26,090 (UK) or 32,690 (CSIC)

[1] Cost for a single hand held meter (UK) or 4 inline meters (Spain).

[2] Analyzer can handle up to 4 gases at additional cost.