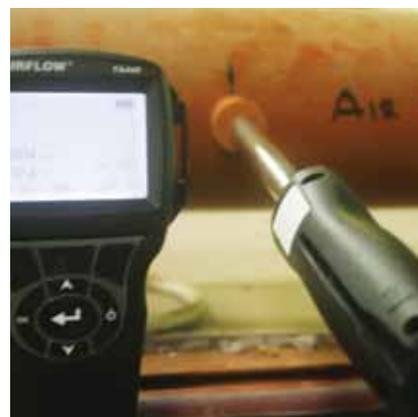


# Technical Manual on Respiration Chamber Designs



**February 2014**  
Edited by Cesar Pinares and  
Garry Waghorn

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# Technical Manual on Respiration Chamber Designs

## Chapter 6: Metabolic Centre of the University of Zurich and ETH Zurich (under construction)

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### AUTHORS

Kathrin Buehler and Marcel Wanner

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## 6.1 Summary

At the time this manual was written (June 2011), the metabolic centre of the University of Zurich and the Swiss Federal Institute of Technology Zurich is still under construction. In its first stage it will be situated at a temporary location and it will consist of two large chambers for cattle, two medium chambers for sheep and goats and two small chambers for smaller animals (piglets etc; not discussed in detail in this manual). It is planned to enlarge the metabolic centre to four chambers per size. Facility air flow is about 910 m<sup>3</sup>/h and temperature ranges from 20 °C to 26 °C without humidity control. The chamber casings are constructed with insulated sandwich panels. Windows are inserted into the casing on each side of the chamber. Chamber volume of the large and medium chambers is about 22.4 m<sup>3</sup> and 9.2 m<sup>3</sup>, respectively. The chambers will be operated at a slight negative pressure (maximal 100 Pa below ambient pressure). Air flow through the chambers will be between 300–1000 L/min (large chamber) and 40–250 L/min (medium chamber). Each of the chambers forms an independent system with its own flow generator, air conditioning unit, animal welfare monitoring and data logging. The two large chambers share a common gas analysis and data acquisition system, so do the two medium chambers. From the flow generators a sub sample is directed to the analyser system by the means of a multiplexer at regular intervals. The duration of these intervals is not yet known. Concentration of water vapour, CO<sub>2</sub>, CH<sub>4</sub> and O<sub>2</sub> are measured with a four-gas analyser. Intervals of gas analyser calibration and recovery tests are not yet defined and will be set according to the dynamics of the chamber and the gas analysers. The large and medium chambers are planned to suit the needs of research animals and operators while enabling monitoring of CH<sub>4</sub> emissions for a maximal time during measurement.

## 6.2 Location of the facility

The physical address of the facility is:

Strickhof  
Eschikon  
Postfach  
8315 Lindau  
Switzerland

Mailing address:

University of Zurich, Vetsuisse-Faculty  
Institute of Animal Nutrition  
Winterthurerstr. 260  
8057 Zurich  
Switzerland

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The metabolic centre is temporarily situated in a part of the agricultural outbuilding of the Strickhof Lindau (Plate 1). This is a centre of excellence in agricultural education, services as well as information and belongs to the Department of Landscape and Nature of the Canton of Zurich. The metabolic centre itself is led and financed by the University of Zurich in close collaboration with the Swiss Federal Institute of Technology (ETH Zurich). For research conducted in the metabolic centre, the animals and stables of the Strickhof Lindau can be used.

Strickhof Lindau is situated about 20 km from the University of Zurich and ETH Zurich (35,000 students in total) and about 10 km from the city of Winterthur (100,000 inhabitants). A highway (A1) is approximately 2 km from the location but there is no industry nearby.

The part of the outbuilding where the metabolic centre is located was separated from the rest of the building by a plywood wall. The floor, walls and ceiling were insulated and floor heating was installed. Heating and cooling maintain a temperature between 20 °C (winter) and 26 °C (summer) within  $\pm 2$  °C without control of humidity. The pressure in the facility is equal to the ambient pressure. Air circulation in the metabolic centre is maintained with a flow rate of 910 m<sup>3</sup>/h by the means of ceiling vents. Ventilation is only turned on when the chambers are in use or when people are present.

All chambers are located in the same room. A separate room contains the equipment for gas analysis, calibration, chamber control as well as data acquisition and processing. Both rooms are air conditioned and ventilated by the facility's system. A dedicated room on the second floor of the outbuilding contains the equipment for the centralised cold and heat production. Feed preparation, stables and cleaning facilities are within 300 m of the metabolic centre on the premises of Strickhof Lindau.

Each respiration chamber is an independent unit with its own flow generator, air conditioning unit (connected to the centralised cold and heat production), data sampling and animal welfare monitoring. The two large chambers are grouped together and share one gas analyser chain and one data acquisition and analysis system (Plate 2). The same design is used for the medium chambers.

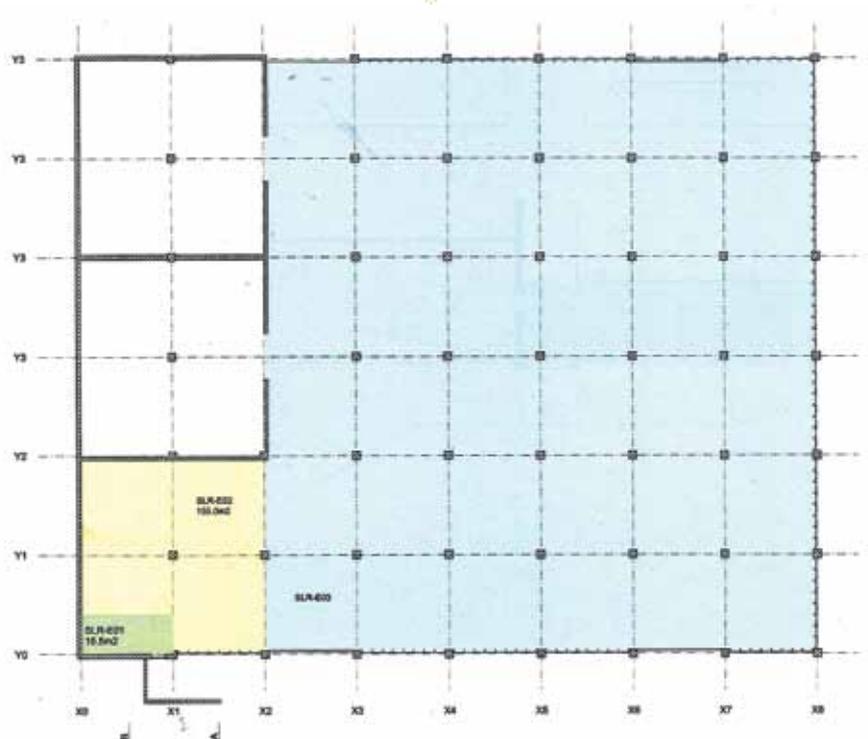
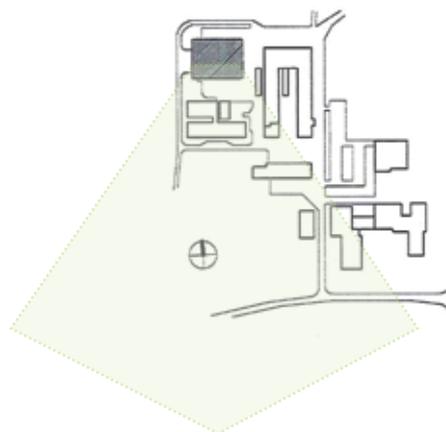
### 6.3 Description of the chambers structure

The respiration chambers were designed to be suitable for a wide range of animal species while guaranteeing accurate measurements of whole animal metabolism and especially of CH<sub>4</sub> production. In addition, the chambers should be as safe and as comfortable as possible for animals and operators.

The design of the chambers is a mixture of existing large and medium chambers in Switzerland, Germany, The Netherlands and New Zealand. It was also taken into account that the new respiration chambers should be suitable for a wide range of research questions. Furthermore, the chambers were built to not just accommodate cattle, sheep and goats but also other animals such as ponies (large chamber) or pigs and camelids (medium chamber). The chamber design also allows easy addition of further measurement devices within the chamber (for example, activity detector) or to the analyser chain (for example, H<sub>2</sub>, NH<sub>3</sub>). The metabolic centre also includes two small chambers for piglets, cats and rabbits but these chambers will not be discussed further in this manual.

**LARGE CHAMBER** (Plate 3): The outside dimensions (cm) are 550 long, 250 wide and 310 high. These numbers include the air conditioning unit, the air lock and the 'chamber core'. The inner dimensions (cm) of the 'chamber core' are 354 long, 230 wide and 275 high ( $V = 22.4$  m<sup>3</sup>) with a suspended ceiling 42 cm below the chamber casing. The 'chamber core' consists

Plate 1: Temporary location of the metabolic centre (**marked yellow and green**) in the outbuilding (**shaded square**) of Strickhof Lindau (SLR-E02: site of the chambers; SLR-E01: Gas analysis and control room).

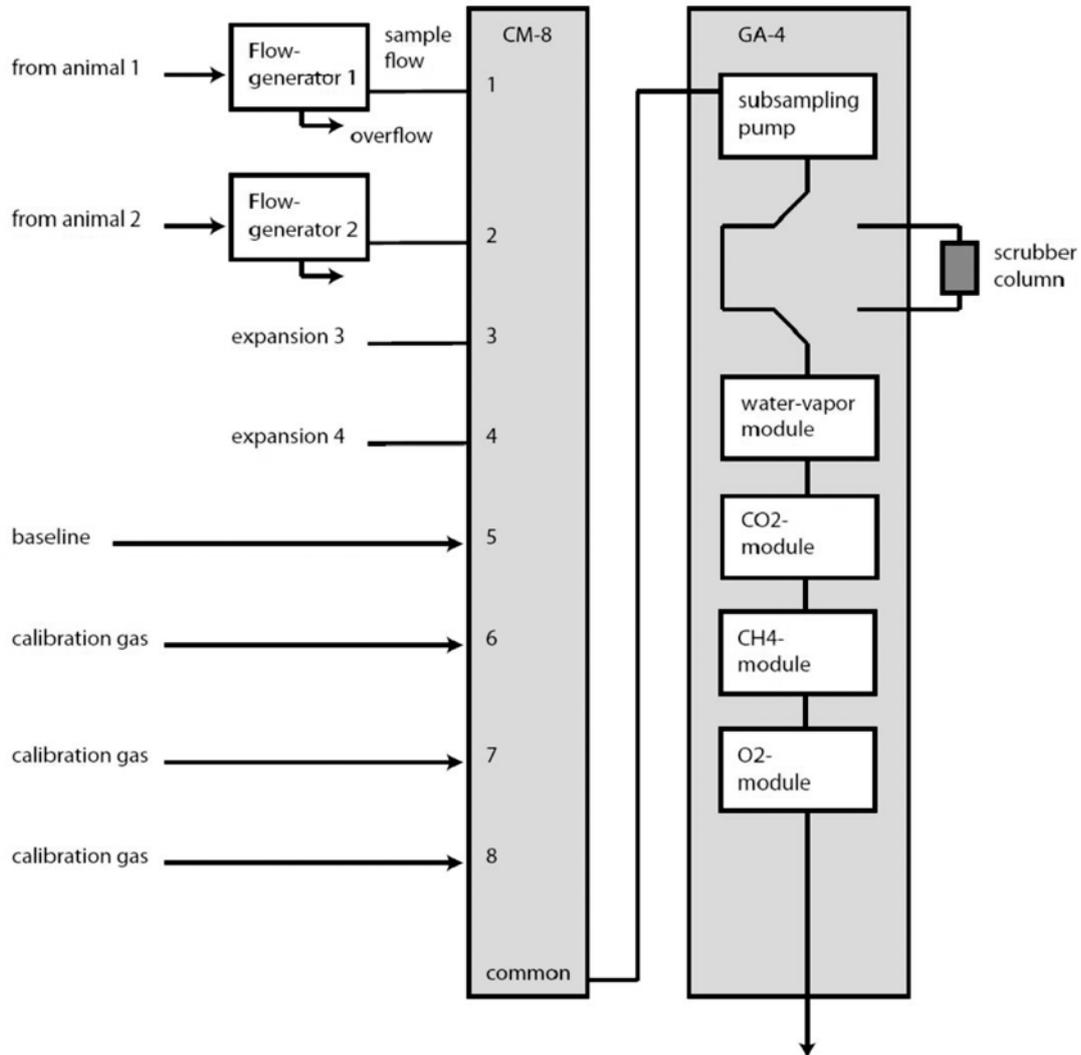


of the animal area (240 cm length, 130 cm width, 200 cm height) and a maintenance aisle for easy access to the animal.

The chamber has a double rear door, closing onto the chamber casing. This door is used to get the animal into and out of the chamber. Rubber seals on both doors and the casing ensure air-tightness. For feeding, milking (if necessary) and exchange of the excreta trays, the chamber can be accessed through the airlock on the far side. The airlock is connected to the chamber by a sliding door sealed with rubber seals. All doors are operated manually. Cables leave (or enter) the chamber through a special airtight sheet for cables, and a tube ensures that additional cables can be brought into the chamber without compromising its tightness in the future.

Temperature (0–40 °C,  $\pm 0.5$  °C) and relative humidity (20–100 %,  $\pm 3\%$ ) are controlled for each chamber separately by an air conditioning unit (monoblock) placed on front of the air lock, and connected to the centralised air conditioning units. Humidity is not regulated

Plate 2: The diagram shows the general set up used for a group of chambers. Only air/gas flows are shown. Data from the GA-4 and data from sensors in the chambers are sent to a computer and are recorded by the data acquisition system. The multiplexer (CM-8) is also controlled by the computer and follows a macro defined by the operator. This set up is repeated for each chamber size. Expansion 3 and 4: shows where the planned additional two chambers will be connected to the multiplexer and the analyser in the future.



the scrubber column at the GA-4 gas analyzer is used for calibration only. Analyzer is heated to improve stability and avoid condensation.

below 10 °C. The air conditioning unit is completely integrated into the chamber casing to prevent leakages out of the chamber. Measures to reduce noise and vibration due to the air conditioning unit are in place and will be used if necessary to minimise animal stress associated with noise.

The chamber walls are made of insulated sandwich panels. The inside consists of stainless steel (EN-Standard 1.4301) and the outside is made of PVDF coil coated galvanised sheet, painted white (RAL9010). Insulation is achieved with 100 mm of polyurethane foam and the panels are glued together (inside and outside) with silicone adhesive. Triple pane windows are inserted into the casing (float glass, U<sub>g</sub>-value 0.7, ED 36 mm). The window frames are electrically heated (dew point controlled) to prevent condensation. The whole chamber is protected against thermal bridges with key and slot joints.

The chamber has a small window in the rear door and a medium sized front window (75 cm wide, 89 cm high). Two large windows (104 cm wide, 153 cm high) on either side of the chamber allow the animal to see its surroundings. Two of these windows are fixed whereas the other two are held shut by an electromagnet and serve as emergency openings. In case of a power failure or violation of set thresholds in temperature, humidity, CO<sub>2</sub>, CH<sub>4</sub> or NH<sub>3</sub> the windows are pushed open by gas rams. One window opens from above, the other from below to allow good circulation of fresh air and to avoid accumulation of toxic gases on the bottom of the chamber.

**MEDIUM CHAMBER** (Plate 3): The outer dimensions of the medium chamber are 400 cm long, 180 cm wide, 310 cm high. The 'chamber core' (inner dimension) is 250 cm long, 160 cm wide and 230 cm high ( $V = 9.2 \text{ m}^3$ ) and has a suspended ceiling 22 cm below the chamber ceiling. The area where the animal is kept measures 170 cm length, 90 cm width, 200 cm height. As with the large chamber, the remainder of the space in the 'chamber core' is used for accessing the animal.

Apart from some minor modifications, the medium chamber is built the same way as the large chamber. The main differences are:

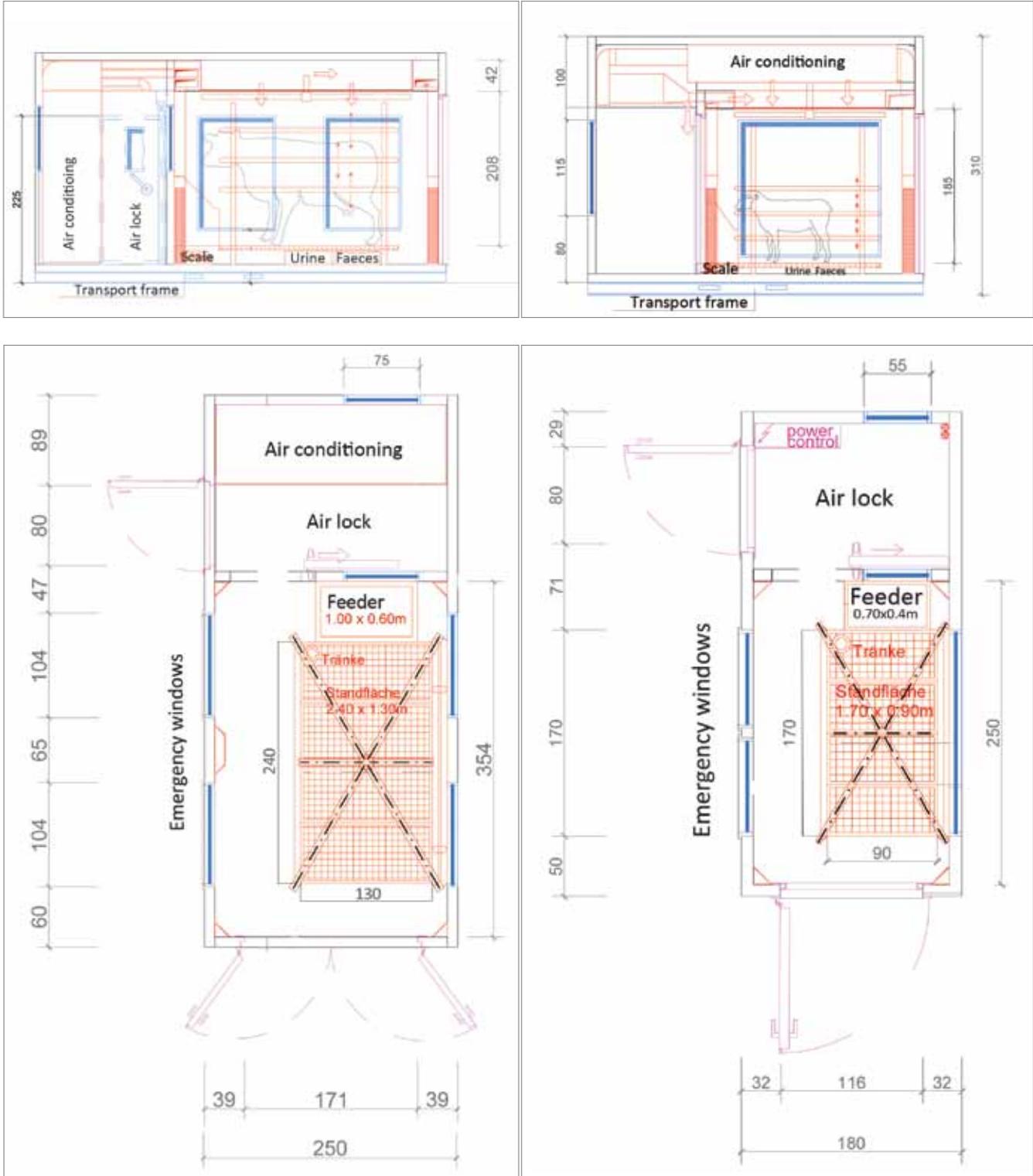
- There is a single rear door, and this entrance is used to get the animal into and out of the chamber.
- The air conditioning unit is on top of the chamber and not in front of the air lock.
- The dimensions of the front window of the medium chamber are 55 cm wide and 115 cm high. Two large windows (170 cm width, 168 cm high) are placed on each side of the chamber. On one side, the window is divided in two halves and serves as emergency opening (same opening mechanism and alerts as in the large chamber).

The large and medium chambers are welded onto a transport frame (stainless steel) with openings on the long side to allow transport with a forklift. The chambers themselves are too heavy (several tons) to be toppled by a rampaging animal. Nevertheless, for additional safety square plates were glued to the room floor to prevent movement.

## 6.4 Animal holding, feeding and cleaning

The animal containment area consists of a highly adaptable stanchion welded to an elevated floor and includes the feeder and water bowl (Plate 4). All parts of the stanchion are made of stainless steel with the exception of the automatic water bowls (enameled) for easy cleaning and resistance to corrosion. At the top of the stanchion metal bars connect the two sides of the stanchion to dissipate any powerful movements of the animal. It was ensured that the adaptation of the stanchion to the animal's size can be easily performed. The animal

Plate 3: Views and dimensions of the large chamber (left hand side, this page) and medium chambers (right hand side, this page). Windows are marked blue.



containment does not cover the complete 'chamber core' and a maintenance aisle allows easy access to the animal for feeding, milking, removing of faecal and urine trays or for minor veterinary treatments.

**LARGE CHAMBER:** A ramp (stainless steel) with an adjustable gradient is wheeled to the chamber and used to lead the cattle onto the elevated floor of the stanchion (29 cm above chamber floor). Once the animal stands in the stanchion, a chain attached to a collar is used to prevent the animal from turning around, but does not restrain head movement or lying down.

The floor is divided into several segments covered with a rubber mat (2 cm thick). The floor segments are between 37.5 and 39.0 cm wide. Depending on the size of the animal, single floor segments can be removed (or added), adjusting the floor to the size of the animal. This system promises easy collection of faeces and urine (female animals) independent of the animal's size. When measuring from male animals, the rubber mat is removed at the likely place of urination and urine is collected by means of a moveable funnel below the elevated floor, which leads to the urinary tray. To prevent the animal from stepping back on the chamber floor a vertical barrier is put in place behind the animal.

To narrow the area of defecation, the width of the stanchion can also be adjusted. A movable side wall can reduce the width of the stanchion, in increments of 6.6 and 8.0 cm. The maximal width of the stanchion can thus be reduced from 130 cm down to 92 cm.

Feeding and milking (bucket milking system) will be twice a day. The feeder is leveled with the stanchion's floor and it is designed to contain about 22 kg of dry matter. The weight of the feed and weigh changes are recorded by the means of load cells below the feeder. Water is provided and consumption is measured by a water meter. Light beams measure total time of lying or standing.

**MEDIUM CHAMBER:** Sheep and goats can either be measured when they are tied with a neck chain (similar to large chamber) or in a metabolic crate. If the animal is tied, the procedure is the same as for cattle: The animal is led up the ramp, tied to the stanchion and the stanchion is then adjusted to the animal's size. The principal construction of the stanchion in the medium chamber is the same as for the large chamber. The floor segments of the medium chamber measure between 25 and 36 cm. The side wall to reduce stanchion width can take one of five positions, each between 6.6 and 8 cm from the other. Thus the width can be reduced from 90 cm to 58 cm. However, primary tests in the factory showed that the minimal width actually used in the medium chamber will most probably be 66 cm, as otherwise the feeder cannot be accessed by the animal.

Feeding and milking (by hand) will be twice a day. Measurement of food and water intake and of standing and lying times are the same as in the large chamber. The feeder of the medium chamber can contain up to 5 kg of feed.

In case a metabolic crate is used, the whole floor of the stanchion can be removed and the crate can easily be wheeled in. The existing crates (Plate 5) will soon be modified to improve animal welfare, without disturbing the air circulation or animal handling.

On average, the animals are kept in the metabolic chamber (large and medium) for two days. Maximal duration of metabolic measurements in the respiration chamber will be four days. The large windows in each chamber allow the animals to see their surroundings, and each other to minimise stress. The windows also ensure daylight in the chamber. If necessary, lamps in the chamber (timer controlled) can be used to increase light intensity. An inbuilt radio in the chambers muffles other noises and keeps the animals calmer in case of sudden sounds.

Exact procedures and the time budget for exchanging animals and cleaning the chamber and metabolic crates are not yet known.

Plate 4:  
Stanchion for the large (**left**) and medium (**right**) chamber. It is adjustable in width and length to the size of the animal (in both pictures the last segment of the floor has been removed). The floor will finally be covered with a segmented rubber mat.



Plate 5: Existing metabolic crate for sheep. The feeding and water trough can be seen in the front. Urine and faeces are collected separately beneath the crate.



## 6.5 Chamber airflow piping and measurement

**LARGE CHAMBER:** Air flow through the large chamber can be set between 300 and 1000 L/min (rule of thumb: increase of CO<sub>2</sub> should not exceed 1 percentage unit and measurement of O<sub>2</sub> consumption should still be possible). At the metabolic centre, the facility's air ventilation system (incoming fresh air) serves as inlet source. Each chamber has its own inlet source. Fresh air from the ventilation system is ducted over a draught damper from the facility air conditioning and ventilation to the chamber is above the suspended ceiling into the chamber. The suspended ceiling is punctured with 8 mm holes, to avoid laminar flow and to reduce air speed. The aim is an air speed of maximal 0.2 m/min in the animal compartment to avoid draught. The air within the chamber is mixed with help of the air conditioning unit at a rate of 80 times per hour. For recirculation, the air leaves the chamber through five openings (20×70×6 cm) at the bottom of the chamber (one in each corner of the chamber and one in the middle of the long side of the chamber). The air is then recycled into the chamber the same way as the fresh air.

Because of the thorough mixing of the air within the chamber, the outlet (air going to the analysers) could be described as a 'spider' hanging just below the suspended ceiling (Plate 3). This 'spider' consists of 6 PVC tubes (inner diameter of 5.5–6.5 cm and capped ends) fixed to a central collector box. Four of these tubes measure 140 cm in length and two 60 cm in length. Air drawn out of the chamber enters through 5 cm holes drilled at 50 cm intervals and is connected to a 12 m long PVC tube with a diameter of 9 cm which takes all of the air (untreated, wet) to a filter (5 µm) and flow meter (one per chamber, capacity can be set between 300–1000 L/min). The flow meter consists of a sealed rotary pump with a controllable flow rate and a mass flow meter that provides flow measurements corrected for standard temperature and pressure. This keeps the chosen and set flow rates constant throughout the measurement period.

Sensors for monitoring temperature and relative humidity (for surveillance only, and not used for analysis) are located in the middle of the chamber, attached to the stanchion. Surveillance analysers to determine gas concentrations are placed in the recirculation air flow tubes

**MEDIUM CHAMBER:** Air flow through the medium chamber can be set between 40 and 250 L/min. Location of the air inlet, the function of the suspended ceiling, and the location of the air outlet are the same as in the large chamber. As in the large chamber, mixing of chamber air is by re-circulating the air 80 times per hour via the air conditioning unit through 4 openings (15×60×4 cm) at the bottom corner of each chamber.

The dimensions of the 'spider' (PVC-C tubes) in the medium chamber are: four arms with 100 cm length and two arms with 35 mm length. The inner diameter of the tubes is 5.5–6.5 cm. The diameter and distance of the holes as well as the working principle are the same as in the large chamber. From the medium chamber the air is drawn through a 15 m PVC tube with a diameter of 5 cm to the flow meter (one per chamber, capacity 40–250 L/min; same working principle as in the large chamber). From there the air is processed the same way as in the large chamber.

## 6.6 Sampling, sample conditioning and analysis

The flow meters are continuously drawing air out of the chambers at 300–1000 L/min (large chamber) and 40–250 L/min (medium chamber). This 'pull-system', together with valves at the inlet of the chamber, always ensures a closely controlled slight negative pressure in the chamber, thus preventing leakages out of the chamber.

An eight-channel multiplexer controls four chamber samples (two not used at the moment),

with three calibration gases (one not used at the moment), one baseline sample, and the flow meter either exhausts all air or sub-samples air leaving the chamber for analysis (Plate 2). This gas is then delivered by a diaphragm sub-sampling pump to the analysers, and is exhausted after passing through the O<sub>2</sub> analyser. All tubing from the flow generators and other gas streams to the multiplexer and to the gas analyser utilise Bev-A-Line tubes.

The multiplexer switches the channels at preset time intervals, defined by the operator. However, only one gas stream (from one of the chambers or baseline or calibration gas) is sent to the analyser at any time.

The analysers are equipped with in built 3 µm filters, after which there is no further treatment of gases (from chambers or baseline) to the analyser. However, for calibration some of the gas samples are dried and scrubbed from CO<sub>2</sub> (see below), so attention has to be paid to the possibility of condensation, which may harm the analysers. The analysers are heated to avoid condensation over a wide range of temperature and humidity, but under extreme conditions insulation, scrubbers (chemical or physical) or condensate traps may have to be installed.

Gas concentrations are measured serially in a “four gas” analyser. The analysers also have an internal temperature control and barometric pressure compensation, so the readout is already corrected to wet standard conditions (0 °C, 1,013 hPa). The detection ranges for CO<sub>2</sub>, CH<sub>4</sub> and O<sub>2</sub> are: 0–10 % (accuracy 1 % of reading, resolution 0.0001 %), 0–10 % (accuracy 1 % of reading, resolution 0.001 %) and 0–100 %, accuracy 0.1 %, resolution 0.001 %, respectively. The fourth gas being analysed is water vapour (range: 0–100 % RH, accuracy: 1 %, resolution: 0.001 % RH, 0.1 dew point) and the water concentration in the air is used for “mathematically drying” the flow rate and the other gas concentrations to remove effects of water vapour. CO<sub>2</sub> and CH<sub>4</sub> are measured using infrared technology and O<sub>2</sub> is measured with a fuel cell. For measuring H<sub>2</sub>O thin-film capacitive technology is used.

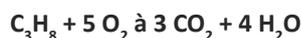
Calibration of the gas analysers (zero and span) will be made before the beginning of each measurement. During measurement the analyser regularly recalibrates automatically. A zero value of the H<sub>2</sub>O analyser is achieved with dry air. The equation for spanning is:

$$\text{Water vapour pressure} = BP \times (F_{iO_2}(\text{dry}) - F_{iO_2}(\text{wet})) / F_{iO_2}(\text{dry})$$

For zeroing the CO<sub>2</sub>, CH<sub>4</sub> and O<sub>2</sub> analyser, nitrogen (99.999 %) is used, and CO<sub>2</sub> and CH<sub>4</sub> are spanned by using a mixed gas (0.5 % CO<sub>2</sub>, 0.1 % CH<sub>4</sub> in N<sub>2</sub> as carrier) Production accuracy: is ± 5% and analytical accuracy: ± 2 % . The O<sub>2</sub> analyser is spanned with dry, CO<sub>2</sub>-free ambient air as it shows an almost constant concentration of 20.95 %. The air is scrubbed from water and CO<sub>2</sub> by using magnesium perchlorate and ascarite.

## 6.7 Gas recovery test

Gas recovery tests are planned to be done with propane burns but the method for methane recovery has not yet been determined. The propane torch is put on a portable precision scale (weight range: 4000 g; resolution 0.1 g) and left there burning with a small flame (duration not yet known) and the scale is connected to a notebook where the weights and exact times are recorded (probably between 1–5 seconds) in an excel file. Calculations will only use data where linear weight loss can be observed (regular, undisturbed burning). Calculation of gas recovery is then done by comparing the expected amount of O<sub>2</sub> consumption and CO<sub>2</sub> production to the values given by the analysers. The expected amount and the recovery rate are calculated using the equations:



and:

$$\text{Recovery rate (\%)} = 100 \times V(\text{Gas})_{\text{measured}} / V(\text{Gas})_{\text{calculated}}$$

The frequency of gas recovery tests will depend on the dynamics of the chambers and the analysers. Until the chamber is properly working, frequency will be higher (possibly several times per day) to ensure that leaks can be detected and repaired. The first tests with animals will not start before good recovery rates are achieved. After a measurement routine has been established, test frequency will be 1–3 monthly. Additional gas recovery tests will be performed after alterations to chambers, piping, pumps or analysers, or malfunctions.

## 6.8 Emissions calculation

For the calculation of CH<sub>4</sub> emission, measurements of outflow rate (FR<sub>e</sub>) and factorial gas concentrations in the air entering (baseline, F<sub>i</sub>Gas) and leaving (F<sub>e</sub>Gas) the chambers are needed. The flow rate is measured as mass but the output is given as L/min, corrected to 0° C and 1,013 hPa. The gas analysers are equipped with internal temperature and pressure sensors and they automatically record gas concentrations at standard temperature and pressure (0° C, 1013 hPa).

To correct for the effect of water vapour on FR and gas concentrations, barometric pressure (BP) and water vapour pressure (WVP) are also recorded. Calculations use the 'mathematically' dried values:

$$\text{Dry flow rate (l/min): } FR(\text{dry}) = FR \times (BP - WVP) / BP$$

$$\text{Dry gas (\%): } \text{Gas}(\text{dry}) = \text{Gas} \times BP / (BP - WVP)$$

**Rate of CH<sub>4</sub> production (l/min):**

$$V_{\text{dot}} \text{CH}_4 = FR_e \times [(F_e \text{CH}_4 - F_i \text{CH}_4) + F_i \text{CH}_4 \times (F_i \text{O}_2 - F_e \text{O}_2) + F_i \text{CH}_4 \times (F_e \text{CO}_2 - F_i \text{CO}_2)] / (1 + F_i \text{CH}_4)$$

In the above equation F<sub>i</sub> and F<sub>e</sub> are the inflow and outflow fractional concentrations of the specified gas. F<sub>i</sub> equals the values of baseline (ambient air) concentrations.

For each chamber flow rates, gas concentrations, temperature, humidity and barometric pressure are available and recorded during the measurement period. The data acquisition and analysis software visualises the recorded data in real time on the computer screen. To correct for slow washout times, an instantaneous correction (also called Z-Transformation) is applied to the raw data. This transformation results in very low response times and almost instantaneous values despite the large volume of the chambers.

A measurement cycle will normally show the following pattern: chamber one; chamber two; baseline; chamber one; chamber two; baseline...etc. The optimal duration of measurements in one chamber and of the total measurement cycle is not yet known. Most probably one chamber will be measured for 60 to 90 s and a cycle will be completed after 3 to 5 min. As soon as these values are known, instantaneous CH<sub>4</sub> emissions can be extrapolated to 24 h.

In the large and medium chambers, data recording and storing continues when the chamber is opened, so every time a door is opening is recorded. To keep disturbances of the chamber environment as small as possible, operators are asked to use the air lock as entrance and to keep the duration of their stay in the chamber to a minimum. An additional indication can be entered manually prior to and after entering the chamber which may also help (and simplify) analyses recorded during feeding, milking or similar disturbances.

## 6.9 Animal welfare and operators' safety

Animal welfare and animal safety strongly influenced the design of the respiration chambers. All possible measures were taken during planning to avoid injuries or fatalities related to chamber malfunctions or gas accumulation. Great care was taken to ensure that the animal will be as comfortable as possible during its stay in the chamber. During measurements the animal can regularly be checked without disturbance by means of video surveillance (infra-red at night). A control monitor also gives information on the status of the chamber and the building (Plate 6).

Supply of fresh air and gas concentrations in the chamber are closely monitored to avoid suffocation of the animal. For safety reasons concentrations of  $\text{CO}_2$  and  $\text{CH}_4$  are monitored in duplicate.  $\text{NH}_3$  is monitored to ensure explosive mixtures of these gases do not eventuate.

The emergency windows are held in place by strong electromagnets. If an alarm is triggered these release and the gas rams are able to overcome pressure difference between the inside and the outside of the chamber and open the windows. The emergency windows open at the following events:

- Power failure
- Temperature exceeds set threshold
- Humidity exceeds set threshold
- Air pressure exceeds set threshold
- Air flow exceeds set threshold (measured within the chamber (air conditioning unit) and by the data acquisition system. Either of them can trigger the opening of the emergency windows)
- Failure of ventilation of the facility (supply of fresh air)
- $\text{CO}_2$ ,  $\text{CH}_4$ ,  $\text{NH}_3$  ( $\text{CO}_2$ , and  $\text{CH}_4$  measured within the chamber and by the data acquisition system) can trigger the opening of the emergency windows.

Events other than emergency openings that will trigger an alarm, and the system for alerting personnel (SMS-Message, cellular telephone) has not been determined but will be standardised and tested by the start of the first measurements.

No special measures for operator safety were taken but the following points will help to reduce the risk of accidents and improve easy handling:

- Good light in the chamber.
- Clear markings of steps to prevent stumbling.
- Strong stanchion with a frame to transfer forces; neither the stanchion nor chamber can be moved in case an animal behaves badly.
- Normal operation of the chamber can be done by one person.

During the first test of the new respiration chambers the main focus will be on animal welfare and safety as well as on handling and operator safety. Necessary adaptations will be made.

## 6.10 Weaknesses of the system

The main weakness of the system, that is, the metabolic centre itself, is its location in the outbuilding. The design of the chambers had to be made according to space limitations and all chambers had to be put in one room, and separation of the large chambers reduced visual contact between the animals. Restrictions by the Commission for Animal Welfare do not allow use of the large and medium chambers simultaneously. However, this situation will improve

Plate 6: Project draft of how the control screen for the chambers may look like.

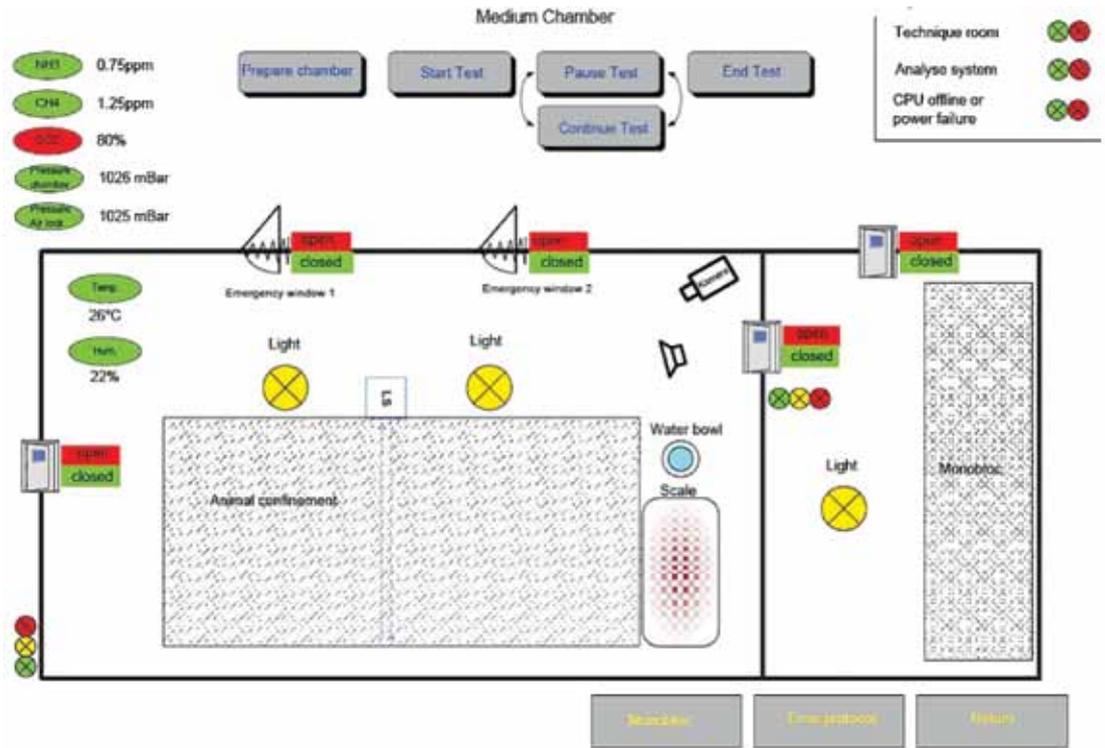


Plate 7: The completed chambers.



after moving to a final location where separate rooms with sufficient height for each size of chamber are planned.

Comments on the technical weaknesses or weaknesses in handling cannot be made at this time, as the system is not yet in use. In June 2011, a prototype each of the large and medium chambers is in place and ready for measurements. These prototypes will be tested and optimized before installing the second chamber (scheduled for April 2012). As many weaknesses as possible will be eliminated before the actual start of the metabolic measurements.

## 6.11 Description of components and equipment suppliers

Components without additional comment are used in/for the large chamber as well as in/for the medium chamber.

### Chamber structure

- The sandwich panels and doors are (from the inside to the outside) stainless steel, 100mm polyurethane foam and PVDF coil coated galvanised sheet: Romakowski GmbH & Co. KG, Buttenwiesen, Germany
- Windows: Fech-Fenstererntechnik GmbH & Co. KG, Buttenwiesen, Germany
- Springs and electromagnets for the emergency windows: Febrotec GmbH, Halver, Germany
- The whole chamber casing including windows and the technique for the emergency windows was assembled by Romakowski GmbH & Co. KG

### Stanchion and feeder

- Huber Metallbau und Stalleinrichtungen AG, Buttisholz, Switzerland

### Air conditioning

- Troges Lüftungstechnik, Vienna, Austria

### Tubing to the chamber and from the chamber to the flow generator

- Hürner Kunststofftechnik, Umwelttechnik, Tagelswangen, Switzerland

### Sensors in the chamber

- Temperature: Jumo Mess- und Regeltechnik AG, Stäfa, Switzerland
- Humidity: Rotronic AG Schweiz, Bassersdorf, Switzerland
- Gases: MSR electronic GmbH, Pocking, Germany

### Control software

- SAIA-Burgess Controls, Murten, Switzerland

### Pumps, analysers, sampling

- Promethion Metabolic Screening System by Sable Systems Europe, GmbH, Berlin, Germany. The Promethion system consists of the following items:

#### *Large chamber*

- Bev-A-Line tubing to connect the flow generator and the analyser

- Main filter (5  $\mu\text{m}$ ) (Solberg, provided by SableSystems)
- Flow generator and mass flow meter with integrated sub-sampling (FG-1000)
- Four-gas analyser with subsampling (GA-4)
- 8 channel flow and calibration multiplexer (CM-8)
- Interface (ACI-12)

#### **Medium chamber**

- Bev-A-Line tubing to connect the flow generator and the analyser
- Main filter (5  $\mu\text{m}$ ) (Solberg, provided by SableSystems)
- Flow generator and mass flow meter with integrated sub-sampling (FG-250)
- Four-gas analyser with subsampling (GA-4)
- 8 channel flow and calibration multiplexer (CM-8)
- Interface (ACI-12)

#### **Data acquisition and logging**

- Standard PC, tower case: supplied by SableSystems Europe, GmbH, Berlin, Germany
- MetaPro acquisition software: SableSystems Europe, GmbH, Berlin, Germany
- ExpeData Professional (analysis software): SableSystems Europe, GmbH, Berlin, Germany

#### **Gas drying chemicals**

- Ascarite (NaOH-coated silica), 20-30 mesh, CAS 81133-20-2: Sigma-Aldrich
- Anhydrous magnesium perchlorate (Anhydrone), granular, CAS 10034-81-8: VWR

Plate 7a: The completed chambers.



## 6.12 Costs of the facility

For the complete metabolic centre (2 large, 2 medium, 2 small chambers) and the ancillary equipment required, including material and work, excluding VAT.

ITEMS	CHF	US\$ <sup>1</sup>
<b>CHAMBER</b>		
Casing including doors and windows	414,000	496,800
Animal compartment (stanchion, feeder)	52,000	62,400
Air conditioning in the chambers	453,000	543,600
Electricity, video, radio	85,000	102,000
Systems for measurement and control	215,000	258,000
Cooling (heat exchange and free cooling) <sup>2</sup>	195,000	234,000
Cold and warm water for the air conditioning <sup>2</sup>	165,000	198,000
Vapour and pressurized air system <sup>2</sup>	91,000	109,200
<b>SABLESYSTEM<sup>3</sup></b>		
Gas analyser	105,000	126,000
Flow generator/mass flow meter	41,000	49,200
Sample switching system	60,000	72,000
Data acquisition and analysis	17,000	20,400
Setup and training	22,000	26,400
<b>GAS RECOVERY<sup>4</sup></b>		
Scale	4,500	5,400
Torch	250	300
Netbook	500	600
<b>CALIBRATION</b>		
Calibration gases	1,300	1,560
Tubing from the gas bottles to the analysers	10,000	12,000
<b>DRYING CHEMICALS</b>		
Ascarite (500 g)	350	420
Mg-Perchlorate (500 g)	500	600
<b>TOTAL COST</b>	<b>1,932,400</b>	<b>2,318,880</b>

<sup>1</sup> 1 CHF = 1.20 USD.

<sup>2</sup> 'First' part of the air conditioning, used for the whole facility and the chambers.

<sup>3</sup> Values transferred from EUR to CHF, 1 EUR = 1.25 CHF; offer includes filters and computers.

<sup>4</sup> Only purchased once; used for all chambers.