# Client Report

**Final report prepared for MAF Policy**

July 2008

## Rapid Assessment of Nitrous Oxide

T J van der Weerden and C A M de Klein

# Rapid Assessment of Nitrous Oxide

## Report prepared for MAF Policy
## [Contract CC-MAF POL_2008-29 (140-4)]

*This report has been produced by AgResearch Ltd for the Ministry of Agriculture and Forestry. All copyright is the property of the Crown and any unauthorised publication, reproduction, or adaptation of this report is strictly prohibited without prior permission.*

## July 2008

T J van der Weerden and C A M de Klein

# Table of Contents

# 1. Introduction

In-field measurements of $N_2O$ emissions are vital to NZ for refining inventory methodologies and developing $N_2O$ mitigation strategies. However, $N_2O$ field experiments are very time consuming and analytically cost-hungry due to the high level of replication and frequency of sampling required to deal with the high spatial and temporal variability of these emissions. The high costs associated with these labour and analytical requirements hamper the gathering of large data-sets that are critical for the refinement of inventory methodologies and the development of mitigation technologies. The development of a fully automated system will therefore significantly enhance the quality of NZ data sets on $N_2O$ emissions.

In recent years, AgResearch invested in an automated mobile gas analyser at Invermay which will greatly reduce the costs of $N_2O$ analysis. However, labour demands remain high as the gas samples are still collected manually.

This project aims to design and build automated $N_2O$ gas chambers that will be added to the existing automated and mobile gas analysis system to provide a fully automated system for rapid assessment of in-field $N_2O$ emissions. Development of a fully automated system, with automatically opening and closing soil chambers will complement the existing automated gas analyser, housed in a caravan. The proposed system will therefore be fully mobile for use in many different (even potentially remote) locations.

# 2. Approach

This project included the following steps:

**Scoping study and visit**

Automated flux chamber systems have been developed with great success overseas (notably Germany and more recently Australia). Some of the feedback received from Australian colleagues has been very positive ("much more data, more often") and they have fine-tuned their design to a version which "is excellent now". We conducted a scoping study on existing automated chamber systems, through literature review and discussions with fellow scientists. We also visited key scientists in Victoria, Australia, examined their automated chambers and obtained the technical detail required.

**Chamber and operating system design**

In close conjunction with Australian colleagues and New Zealand engineer(s), we designed an automated chamber and operating system that meets key criteria. These include:

- Appropriate design for New Zealand conditions (e.g. cooler/higher rainfall/land-use)

- Chambers to be strong yet relatively light-weight

- System can be linked to the existing analytical system

- Portable

- Chambers lids to fully open to ensure rainfall not blocked

- Chambers fully air-tight when shut

- Options/check for reducing the risk of malfunction of the system

**Chamber and operating system construction and testing**

We oversaw the construction of a prototype chamber by engineer(s) to ensure required specification and deadlines were met.  Any alterations that were required were addressed.

# 3.   Outcome

## 3.1   Scoping study and visit

A review of international literature, correspondence with key overseas scientists in Denmark, USA, Germany and Italy, and a visit to DPI Victoria (Horsham and Hamilton) and University of Melbourne helped determine the most appropriate design for the New Zealand situation.

Automated chamber designs can be divided into two types, (i) where the lid opens similar to a box with flaps (Butterbach-Bahl et al., 1997; Meyer et al., 2001) and (ii) where the lid is lifted or slides off to the side (Ambus and Robertson, 1999; Scott et al., 1999; Smith and Dobbie, 2001).

Excellent technical detail was gained from a fact-finding trip to Australia, where Australian scientists and researchers (Kevin Kelly, Prof. Richard Eckhard, Dr. Sally

Officer, John Graham, Dr. Deli Chen, and Dr. Stefan Arndt) were more than willing to assist with this project. Key details were obtained on:

- Chamber height with respect to crop type. This included the use of "extensions" positioned between the base and chamber when dealing with increasing crops height.

- Avoiding leakage, with particular emphasis on the design of the lid closure and sealing.

- Continuous soil/air temperature and soil moisture measurements inside and outside the chambers.

- The practice of using of two bases per chamber, thereby reducing the medium to long term variation in environmental conditions within the chambers and the associated pasture/crop growth and soil processes.

- Dealing with rainfall events, where chambers would automatically open in response to a rainfall event.
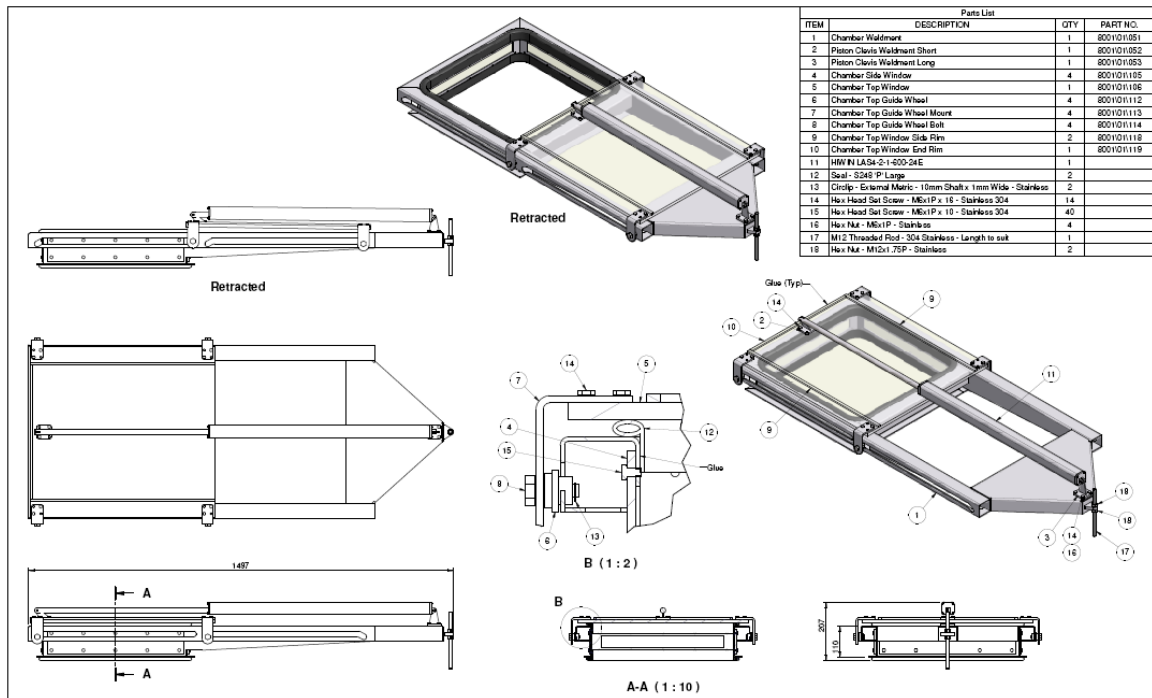

## 3.2  Chamber design

The automated chamber design needed to meet some key criteria for effective application in pasture systems, as listed in Section 2.  Engineers based within the Textile Science and Technology section of AgResearch at Lincoln were consulted on the chamber and operating system design.  It was decided that a design with a sliding lid controlled using a linear motor would ensure rainfall inside a chamber, when open to the elements, was not blocked by vertically opened lids.  Other aspects of the design include (i) simple yet effective lid closing mechanism to ensure good sealing with minimal risk of failure, (iii) the use of aluminium for the metal construction to lighten to load when transporting, (iv) and using a Perspex lid to ensure light can enter the chamber when closed.

Figure 1 shows the chosen design.  The lid is operated by way of a linear motor, controlled by the operating system (section 4.3).  The Australian colleagues stressed the need for ensuring the chamber did not leak.  To achieve this, the lid is fitted with 4 small wheels (2 on each side) which roll on a rail with a cam at the end (Fig. 4).  The linear motor will push against the lid, with the cam forcing the lid down onto the seal.

To minimise the potential for soil and pasture conditions within the chamber to vary from the external conditions over time, there will be two chamber bases inserted into the soil for every chamber.  This will allow the chambers to be moved regularly.  Soil moisture and temperature probes will remain with each base to ensure undisturbed, continuous

monitoring of these key soil parameters.  Such data collection is required to ensure data on diurnal patterns is collected, which can then be interrogated and interpreted with the diurnal $N_2O$ fluxes.

Figure 1: Chamber design for automated gas sampling from soils.

| Parts List | | | |
|---|---|---|---|
| ITEM | DESCRIPTION | QTY | PART NO. |
| 1 | Chamber Weldment | 1 | 8001\01\051 |
| 2 | Piston Clevis Weldment Short | 1 | 8001\01\052 |
| 3 | Piston Clevis Weldment Long | 1 | 8001\01\053 |
| 4 | Chamber Side Window | 4 | 8001\01\105 |
| 5 | Chamber Top Window | 1 | 8001\01\106 |
| 6 | Chamber Top Guide Wheel | 4 | 8001\01\112 |
| 7 | Chamber Top Guide Wheel Mount | 4 | 8001\01\113 |
| 8 | Chamber Top Guide Wheel Bolt | 4 | 8001\01\114 |
| 9 | Chamber Top Window Slide Rim | 2 | 8001\01\118 |
| 10 | Chamber Top Window End Rim | 1 | 8001\01\119 |
| 11 | HIWIN LASx-2-1-600-24E | 1 | |
| 12 | Seal - S248 'P' Large | 2 | |
| 13 | Circlip - External Metric - 10mm Shaft x 1mm Wide - Stainless | 2 | |
| 14 | Hex Head Screw - M6x1P x 16 - Stainless 304 | 14 | |
| 15 | Hex Head Set Screw - M6x1P x 10 - Stainless 304 | 40 | |
| 16 | Hex Nut - M6x1P - Stainless | 4 | |
| 17 | M12 Threaded Rod - 304 Stainless - Length to suit | 1 | |
| 18 | Hex Nut - M12x1.75P - Stainless | 2 | |

Retracted

Retracted

1497

A

A

B (1 : 2)

Glue

B

A-A ( 1 : 10 )

## 3.3   Operating System design

In addition to the design and construction of new automated chambers, this project also required the design and construction of an operating system.  The operating system will control the trace gas analyser, multisolenoid valve unit for switching airlines between chambers and the motors opening and closing the chamber lids.  Environmental sensors will capture data on soil moisture and temperature for several of the chambers, in addition to ambient soil moisture, soil and air temperatures and rainfall.  The software will allow for the chambers to automatically open if there is a significant rainfall event. This will ensure the treated areas within the chambers are subject to the same rainfall regime as outside the chambers.

The field caravan currently used for some of the $N_2O$ research has a series of solar panels attached to it.  It has been calculated that the automated chamber system will require more power than the potential supply of these panels.  Therefore, the chamber system also includes a petrol-powered generator with sufficient capacity to ensure the system runs without power outages.  The design will ensure power generated by the

solar panels is utilised first, with the generator auto-starting when the power supply is reduced to a set threshold.

A GPRS modem will be included in the design, allowing remotely collected data to be sent via telemetry to the office computer. Data that can be sent includes $N_2O$ measurements, environmental data, power supply details, and alerts if there are any issues (e.g. chamber not fully closing, airlines blocked for a particular chamber) that need to be addressed. A schematic diagram of the complete automated chamber system is shown in Figure 2.

Figure 2: Schematic diagram of complete automated nitrous oxide measurement system.
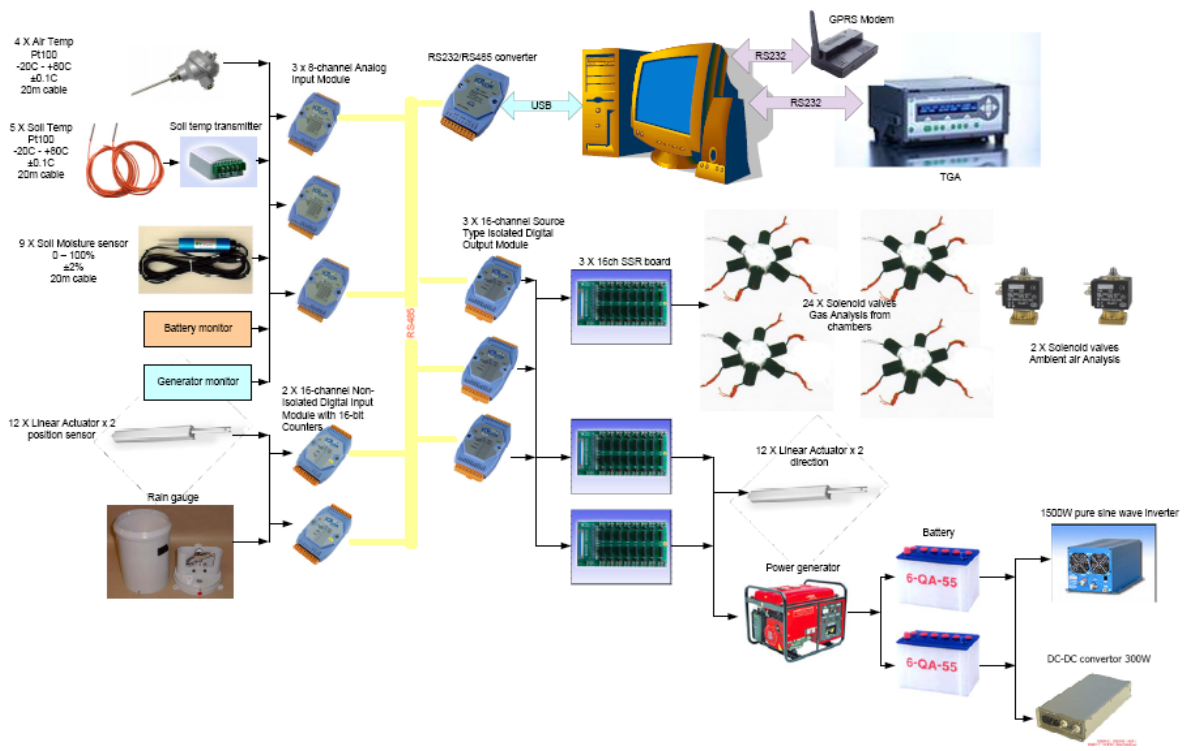


## 3.4  Chamber and system construction and testing

The available budget allowed for a 9-chamber system to be built. This provides a sufficient number of chambers for field studies where intensive measurements could be made from 2-3 treatments with adequate replication.

To determine if design alterations were required, a prototype chamber was constructed (fig. 3 and 4). One alteration that came to light was the benefit in adding a wheel to the bottom end (Fig. 3, far end) to aid with the repositioning of the chamber from one base to another.

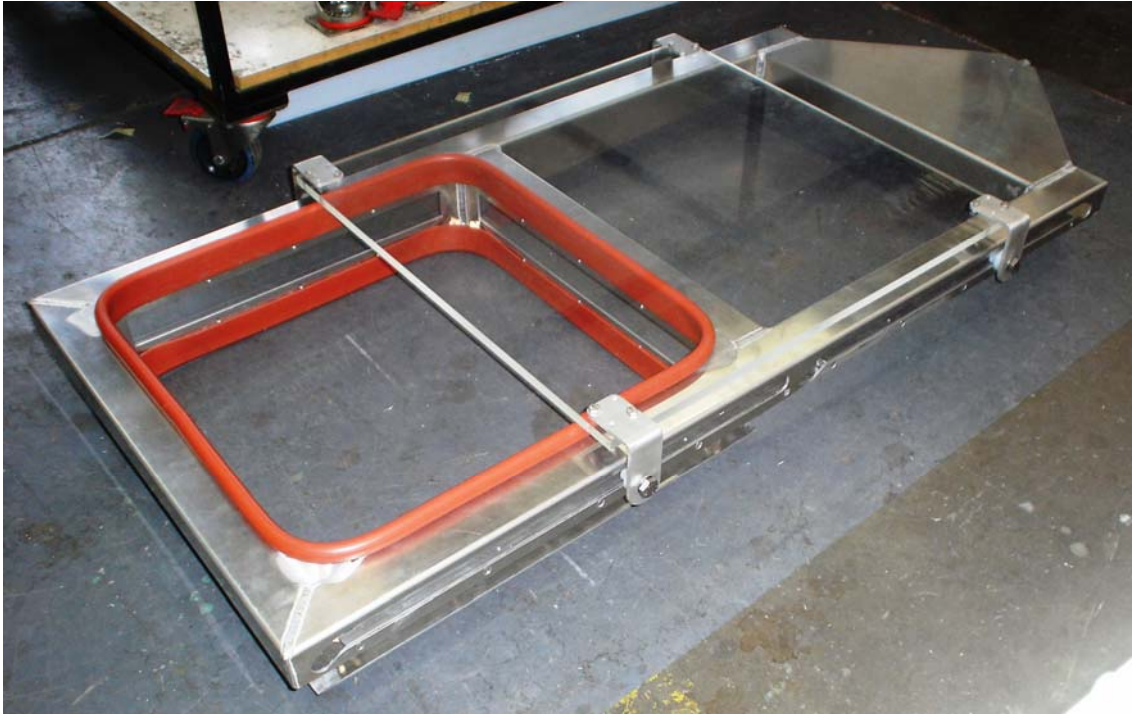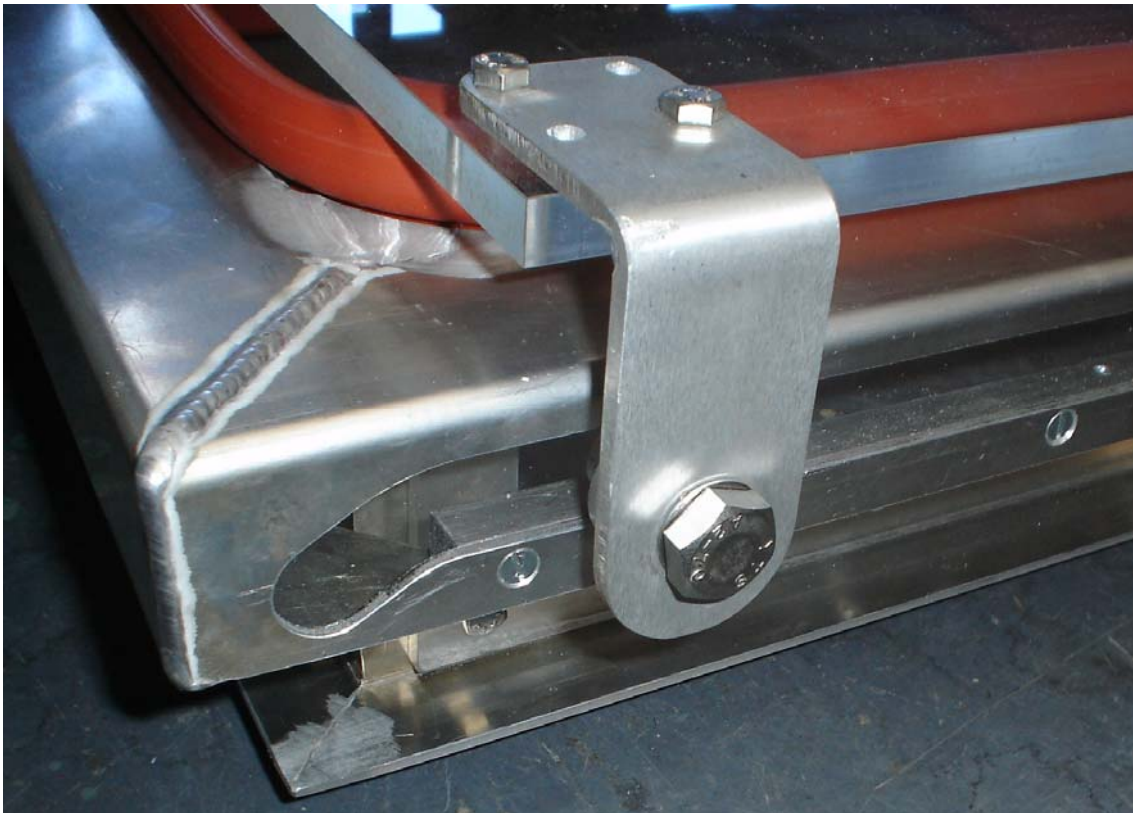Fig. 3. Prototype chamber showing lid approximately half closed. Linear motor still to be attached to lid.



Fig. 4. Close up of cam to assist with sealing of chamber when shut.

## 3.5   Potential benefits of the automated chamber system

The current approach to quantifying $N_2O$ emissions from soils relies on a closed chamber approach where one or two flux measurements are made per 24hr period by taking 2-3 headspace gas samples at regular intervals (typically 0 and 30 minutes or 0 and 60 minutes) for each flux measurement.  The gas samples are stored in small glass vials, which are then sent to a gas chromatography laboratory for determination of $N_2O$ concentrations. Sometimes there can be a 3-4 week delay before the results are received and $N_2O$ fluxes can be calculated.  These results can influence the frequency of field measurements; therefore this type of delay can result in a less-than-optimal sampling regime being practiced.

This new automated chamber system will allow the following:-

1.     More frequent, near-continuous determination of $N_2O$ fluxes.  This system will allow trials to be designed where up to 12 flux measurements per 24-hour period can be made: **this is a quantum leap in our capability to measure $N_2O$ emissions from field sites**.  This provides the opportunity to measure $N_2O$ fluxes on a diurnal basis. The Australians have previously commented on their automated system producing "much more data, more often".  With more data comes the ability to better determine the processes responsible for the production of the measured emissions.

2.     Remote operation.  This design allows the chamber system to be operated remotely, where collected data is sent via telemetry to the office.  This, together with the automated sampling and analysis, will reduce labour costs associated with the collection of gas samples.

3.     The utilisation of various chamber combinations, with the current system including a 9-chamber configuration.

4.     Future proofing. The system has been designed with future proofing in mind.   A further 3 chambers can be added to the existing 9 with ease (virtually "plug and play"), providing a system of 12 automated chambers.  With minor software and hardware alterations, chamber numbers can be further increased.

Consideration of the risk of malfunction has been included in the physical design of the chambers.  The method of lid closure, including the motors and sealing, has been designed to minimised failure in the field.  However, in the unlikely event of a malfunction, the software system, which was designed using "Labware", will be able to detect any failures with chamber lid closure and send an appropriate text message via modem to one or more cell phones, in addition to an alert or message to a website

address accessed from the office. Any potential malfunction by the trace gas analyser will also be detected by this software and an appropriate message sent to a cell phone with data also being sent to a website accessed from the office. This ensures that malfunctions are dealt with swiftly, thereby reducing the risk of data loss.

While this new automated chamber system can be utilised for any type of field experimentation to measure $N_2O$ emissions, it especially provides the opportunity to better quantify frequent changes to $N_2O$ fluxes. $N_2O$ fluxes can increase rapidly as a consequence of changes to key drivers. Examples of events that affect key drivers include rainfall/irrigation, soil disturbance (e.g. cultivation/animal treading/crop establishment), N inputs (e.g. excreta/fertilisers - with and without inhibitors/ animal waste/residues), and mitigation tools (e.g. inhibitors/diluted urine/dung). The automated chambers will greatly enhance our ability to describe these flux changes thereby will allow us to more accurately measure $N_2O$ emissions from various farming practices.

# 4. Acknowledgments

# 5. References

Ambus, P.and Robertson, G.P. 1998. Automated near-continuous measurement of carbon dioxide and nitrous oxide fluxes from soil. *Soil Sci. Soc. Am. J.*, 62: 394-400.

Butterbach-Bahl, K., Gasche, R., Breuer, L. and Papen, H. 1997. Fluxes of NO and N2O from temperate forest soils: impacts of forect type, N deposition and of liming on the NO and N2O emissions. *Nut. Cycl, Agroecosys.* 48: 79-90

Scott, A., Crichton, I., Ball, B.C. 1999. Long-term monitoring of soil gas fluxes with closed chambers using automated and manual systems. *J. Environ. Qual.* 28: 1637-1643.

Smith, K.A. and Dobbie, K.E. 2001. The impact of sampling frequency and sampling times on chamber-based measurements of N2O emissions from fertilized soils. *Glob. Change Biol.* 7: 933-945

Meyer, C.P., Galbally, I.E., Wang, Y.P., Weeks, I.A., Jamie, I. and Griffith, D.W.T. 2001. Two automated chamber techniques for measuring soil-atmospheric exchanges of trace gases and results of their use on the OASIS field experiments. CSIRO Atmospheric Research Technical Paper No.51. Pp 33.