GreenFeed standard operating procedure

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OVERVIEW

The GreenFeed (GF) standard operating procedure (SOP) will comprise 6 main sections

1. Background
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This manual provides an overview of gas emissions by cattle, because understanding the origin of methane (and eructations) is important when understanding GF operation. The focus is on operation at pasture, and functional details are available on the c-lock website.

There are about 80 GreenFeed units operating globally, and the majority are associated with barns or feedlots, so they are connected to mains electricity, which avoids the challenge of maintaining battery power in a field situation. The current models (#76 & 77) owned by AgResearch have self-starting generators (a recent innovation) to maintain battery power, which is a considerable improvement over previous models (#6 & 7). These were the 2nd and 3rd GF in commercial operation, and in addition to limitations associated with solar panels (that were unable to supply sufficient power when day length was less than 12h, or overcast) many advances have been made , especially in pellet delivery, auto-calibration and data handling/analysis.

Greenfeeds have been used in New Zealand indoors (AgResearch, Palmerston North) by Drs Cesar Pinares-Patino and Arjan Jonker and outdoors at DairyNZ in Taranaki, by Garry Waghorn and in Hamilton with Erin Garnett (Erin.Garnett@dairynz.co.nz. Newly purchased GreenFeeds will provide more opportunity for operators to gain expertise, including Russel McAuliffe, Anna Taylor (Anna.Taylor@agresearch.co.nz) and others in the Lincoln group headed by Robyn Dynes, (Robyn.Dynes@agresearch.co.nz).

Paul Lovejoy (AgResearch, Palmerston North) is the engineer who has been involved with all the GreenFeeds to date and was responsible for trailer-mounting and initial operation of the newly acquired models. Paul has a good knowledge of their operation, and can be

helpful with diagnosis of failure, but this is not his role. Questions should be directed to a local electronics engineer, or to the manufacturers (C-lock Inc.); their engineer is Mike Billars mbillars@c-lockinc.com

GreenFeed operation can be straight forward, but there is a need for careful monitoring and maintenance, as well as requirements for cow training, restricting over-enthusiastic cows, and data analysis. Operation and data acquisition is best checked daily, every day. This can be done remotely and is needed to ensure cows are visiting, that none are dominating, that pellets are delivered. On-line checking might only take 15 minutes, but it is important in diagnosis of problems, e.g. a pellet blockage that means cows are not rewarded for visiting. The seven days a week operation suggests 2-3 persons with operational knowledge are required, and maintenance of fuel and pellet supplies, as well as moving between paddocks will require staff input every day.

It is much better to prevent problems than allow them to happen and try to rectify later.

BACKGROUND

GreenFeed$^{(TM, patent pending)}$ (GF) is a nonintrusive system for estimating methane (CH_4) and carbon dioxide (CO_2) fluxes from cattle choosing to visit the units. The GF is mounted on a trailer, and moved with the herd, and animals may choose to visit and eat pellets dropped at about 20 second intervals for 3-4 minutes and while they are eating with their head in the “hood” gases in breath are measured (Figure 1). The system includes animal identification, feed dispensing, air handling, gas measurement, gas calibration, electronics, communication, and data handling systems. Animal visits are monitored and restrictions can be put in place to prevent excessive use, through radio frequency identification (button) ear tags that identify individuals visiting the units. A chute is attached to the unit to ensure single animal access (front cover).

A fan pulls air past the animal’s muzzle into ducting where airflow rates are measured and subsampled for determination of CH_4 and CO_2 concentrations. The GF include various calibration systems to ensure an appropriate air flow, gas sensor operation, as well as air recovery and animal head position. For example, there is a routine release and recovery of propane gas tracer released in both the hood during animal visits, and into the internal

ducting between animal visits. In addition, CH_4 and CO_2 recoveries are determined routinely, automatically from gas bottles in the “tool box” and, and CO_2 manually from “paint ball” canisters that operators must undertake every 2 weeks. So, operation and interpretation of measurements is complicated, semi-automated and requires good attention to detail.

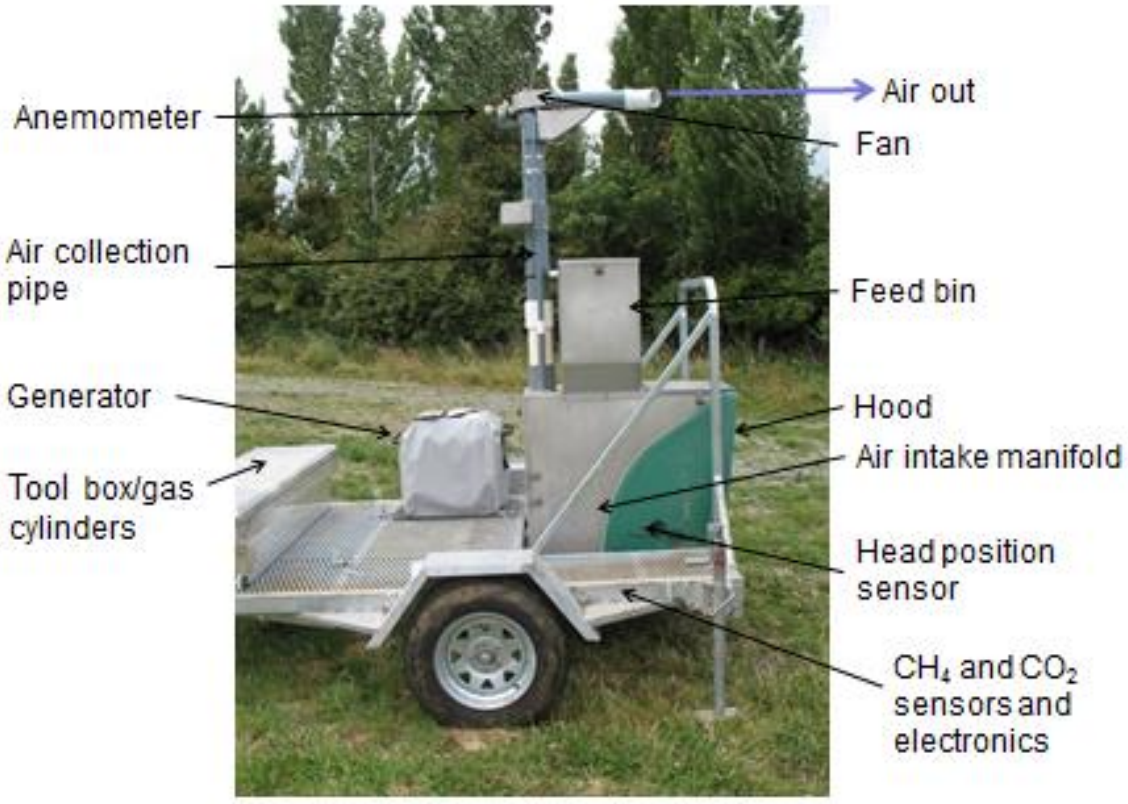


Figure 1. Layout of trailer mounted GreenFeed.

Emissions are calculated from air flow and concentrations of gases in air passing the sensors, with correction for background concentrations, described by Waghorn and Jonker (2016). Wind is unlikely to affect gas recovery, with correct set up, but the filters must be kept clean and dry to enable air flows of about 40L/second. Most methane is emitted in eructations (belches) that occur at 1-2 minute intervals (Figures 2 and 3), so the animal must have its head in the hood for a minimum of 2 minutes to obtain a viable measurement. Operators are alerted to low airflows and sometimes to feed-drop

blockages, but in this complex system there are potential problems and awareness is crucial to success.

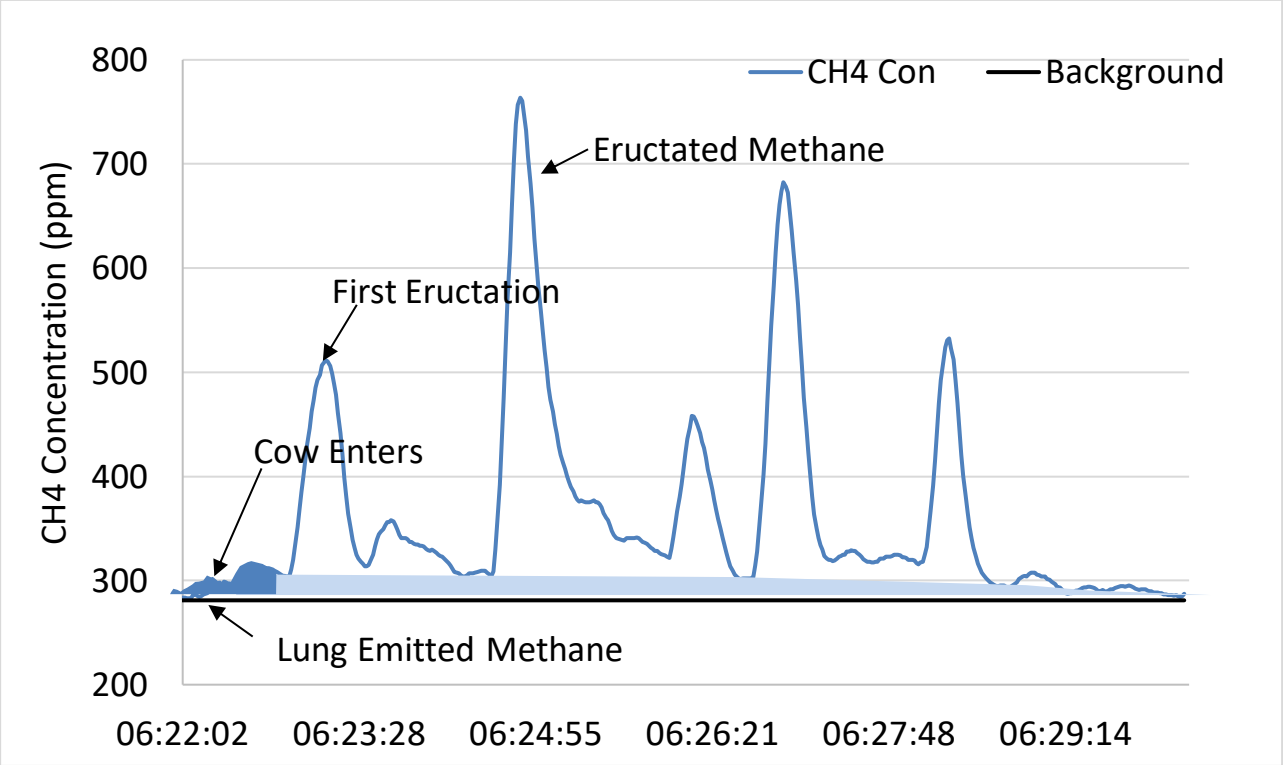


Figure 2. An example of methane concentrations during a visit to GreenFeed, showing the intermittent eructation over time (x axis)

While most data calculations are undertaken automatically (and are not amenable to operator adjustment), there is a need to monitor animal use (so some do not 'dominate' the system), and to ensure fuel supplies are maintained for the generators, that pellets are available and there are no blockages, and the data are transmitted to the c-lock server (usually hourly). In addition, units will need to be moved, the chute attached and CO_2 recoveries need to be undertaken.

Daily estimates of methane and CO_2 emissions are made from a number of short measurements, usually over 2-3 weeks. Each measurement is only 2-7 minutes in duration (Figure 2) and cows usually visit 1-3 times daily. Restrictions (electronic control)

are imposed on over-enthusiastic users, limiting pellet drops to e.g. every 4 h, but few cows visit more than 3 times/day. Typically, 50-70% of cows at pasture visit GF, and the numbers visiting does not seem to relate to feed supply (stocking rate). These factors, as well as the circadian pattern of visits are important because they help planning numbers of cows and duration of measurement period (days/weeks).

The GF system differs from other measures of methane (e.g. chambers, SF_6 marker dilution; using gas collection yokes), so operators need to familiarize themselves with physical operation of GF, web-based control and monitoring of operations, and animal data acquisition and interpretation. It is important to appreciate that animals accessing a GF unit are not independent units, and whilst individual emissions can be estimated, statistical comparisons between treatments are not possible unless there are true replicates available.

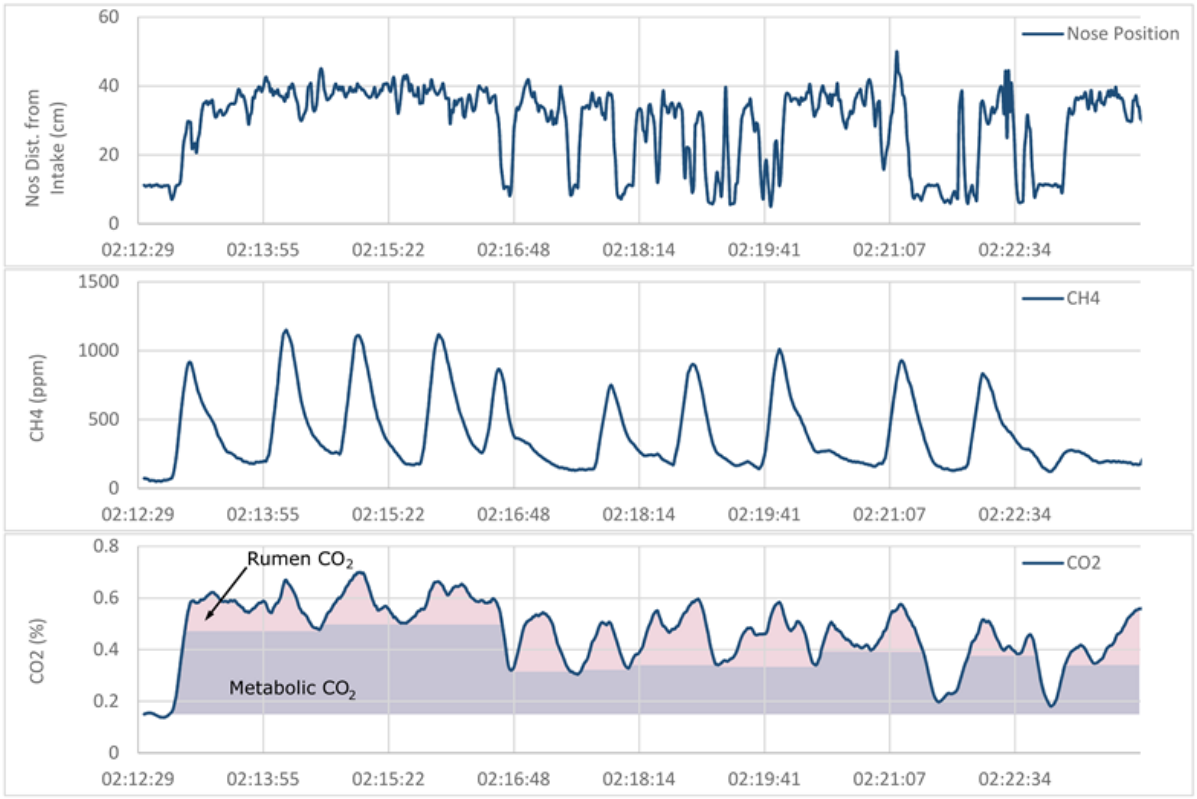


Figure 3. A record of cow information when visiting GreenFeed, showing nose position (top) methane concentration (middle) and carbon dioxide (bottom) from metabolic and rumen origins

The new GreenFeeds are highly automated, so there is very little data manipulation required by the operator. Data are adjusted automatically, and any unreliable information (e.g. where the animal moves its head out of the hood during measurement) is removed. In addition to routine machine maintenance and moving with the herd, the operator needs to log on to the GreenFeed site to monitor daily operation, and this can include downloading information summarising animal use and gas emissions for analyses.

Analyses may include estimates of daily emissions of CO_2 and methane for individual cows, the circadian pattern of visits, number of pellet drops for individuals, time of day that individuals visit, changing patterns of visits (frequency/time of day over time), and cows that start and/or cease visiting GF. The choice of analyses are the prerogative of the researcher, and are not detailed here.

Operators must firstly familiarise themselves with the GreenFeed web page, where a lot of information is available, though not necessarily related to the units (numbers 76 and 77) owned by Agresearch. Most information is generic to all Greenfeed units, and some is dated, but also updated. Nevertheless, interpretation can be challenging.

C-LOCK WEBSITE

GreenFeeds data are located at the c-lock website, and access may require either google chrome or firefox; http://www.c-lockinc.com/. The login is 'hiding' on the top right of the screen. Once logged in, first time users need to open links associated with data, animals, settings etc. Try to find links that help you gain an overview of the process (in 'other'), but at the same time work with a prior user. Turn the GF on; only then will a lot of the functions become apparent. With assistance, general proficiency could be attained in a week; without – plan on 3 weeks. Ask anyone new to this system; it is not straightforward and some instructions are challenging!

The front page of the GreenFeed site includes a range of projects their equipment has been involved in, in France, Sweden, four sites in the United States, and one in Ireland,

and selected publications using their technology, the first in 2011. Any publication deemed negative in any way is avoided (e.g. Hammond et al., 2015; 2016).

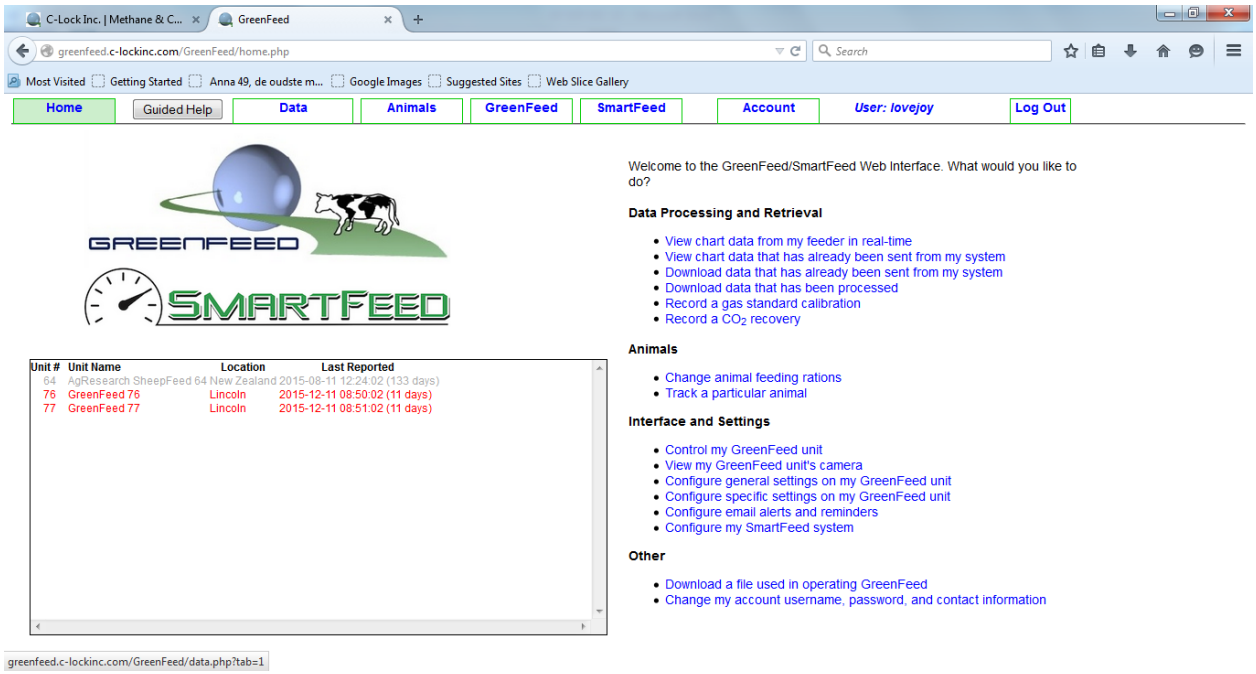


Figure 4. Front (home) page of the GreenFeed login showing tabs associated with instructions (Guided help), Data, Animals and GreenFeed status.

The importance of opening (downloading) links in Figure 4 should be fairly obvious; these provide instructions to assist users. The links also provide visual depictions of web pages which help users navigate around the Greenfeed site, but all information on the c-lock website is protected and cannot be copied, for example into this SOP. For this reason, users might be guided to a page, rather than have information presented/repeated here.

The first six links (data processing and retrieval) relate to information generated or required by your GreenFeed; the first two enable data to be viewed, the second two enable data to be downloaded, the option 'record a gas standard calibration' is not necessary in the models with auto-calibration, but the last sheet enables the manual CO_2 recovery/calibration data to be recorded and uploaded New users need to familiarise themselves with these and other links, especially after some animals have visited GreenFeed.

The Animal links (also accessible via the ‘Animal tab’; Fig 4) enable data to be viewed and settings to control pellet dispensing to individuals to be accessed (Change animal

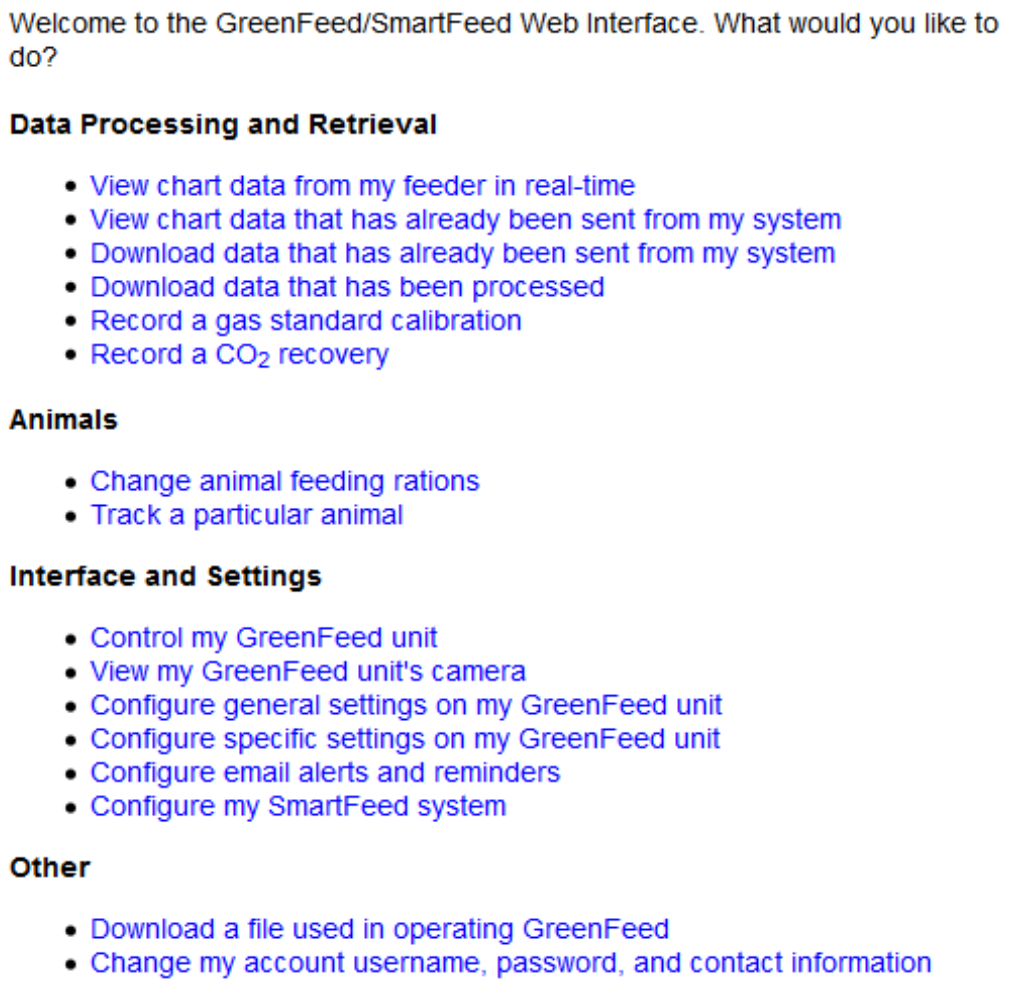
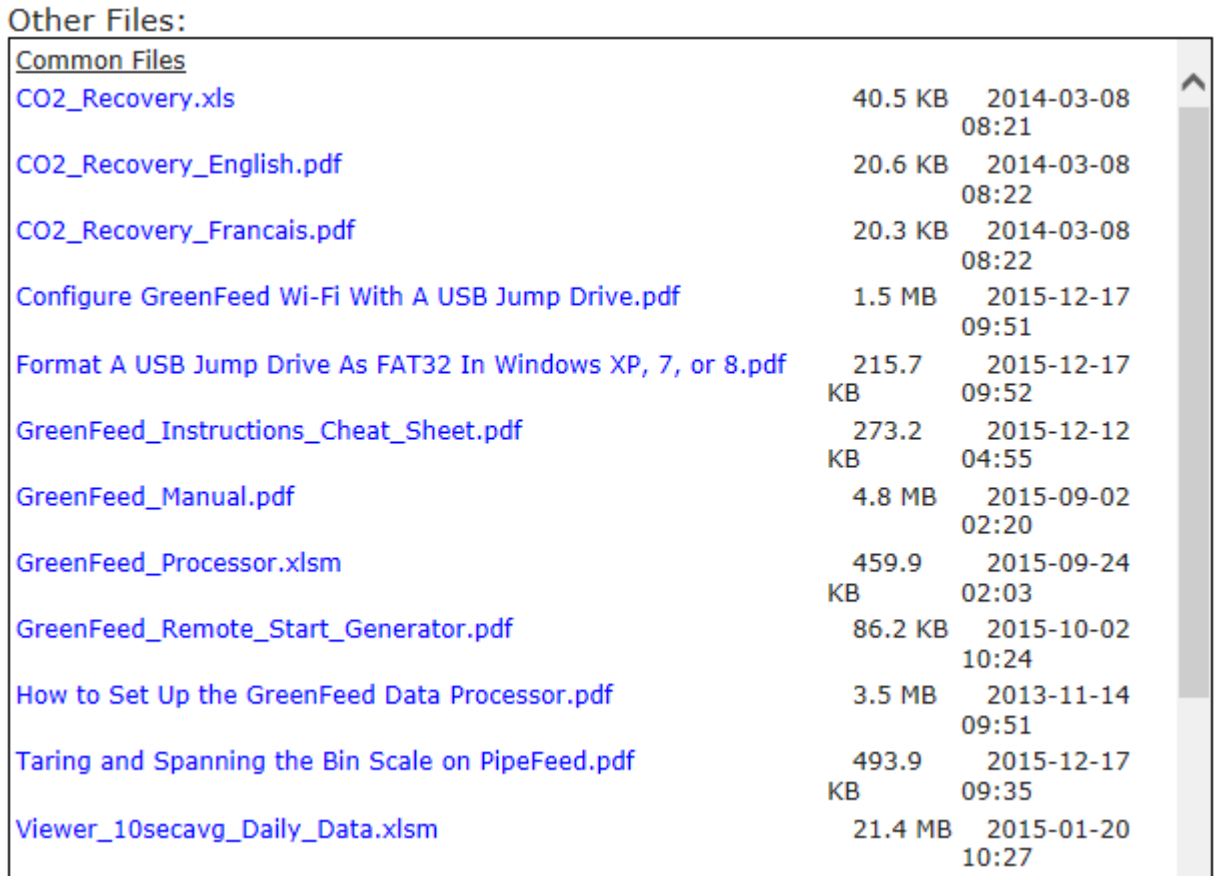


Figure 5. List of links available to users logged into the c-lock website (as at 21/12/2015).

values). Additional controls are available via the ‘Interface and settings’ – or the GreenFeed tab (Fig 4). GreenFeed is best controlled via this interface and users can adjust many aspects of its operation, for example turning the fan on, or only having it on when an animal enters GF (Auto). Some settings are for ‘advanced’ operators, and others are for learners. Be careful when adjusting parameters termed ‘advanced’, and seek assistance unless you are sufficiently competent to be able to monitor the impact of changes.

The ‘other’ tab (Figs 4 and 5) providing access to information to assist GF operation.

The GreenFeed manual (Fig 6) provides an overview of gas emissions from livestock, feeder controls, calibration, CO_2 recovery filter cleaning and details concerning settings and data handling. There is no need to repeat these here, other than to emphasise aspects of especial importance. The downside of the instructions is that some aspects relate to other feeders, for example solar powered, or without auto calibration


Other Files:

Common Files

CO2_Recovery.xls	40.5 KB	2014-03-08 08:21
CO2_Recovery_English.pdf	20.6 KB	2014-03-08 08:22
CO2_Recovery_Francais.pdf	20.3 KB	2014-03-08 08:22
Configure GreenFeed Wi-Fi With A USB Jump Drive.pdf	1.5 MB	2015-12-17 09:51
Format A USB Jump Drive As FAT32 In Windows XP, 7, or 8.pdf	215.7 KB	2015-12-17 09:52
GreenFeed_Instructions_Cheat_Sheet.pdf	273.2 KB	2015-12-12 04:55
GreenFeed_Manual.pdf	4.8 MB	2015-09-02 02:20
GreenFeed_Processor.xlsm	459.9 KB	2015-09-24 02:03
GreenFeed_Remote_Start_Generator.pdf	86.2 KB	2015-10-02 10:24
How to Set Up the GreenFeed Data Processor.pdf	3.5 MB	2013-11-14 09:51
Taring and Spanning the Bin Scale on PipeFeed.pdf	493.9 KB	2015-12-17 09:35
Viewer_10secavg_Daily_Data.xlsm	21.4 MB	2015-01-20 10:27

Figure 6. Some files providing instructions for using GreenFeed that users need to view or download as part of their familiarisation.

The Remote start generator manual has been developed since the AgResearch GreenFeeds were purchased and provides a useful guide to settings enabling smooth operation, such as shown in Fig 9. However, other files are nearly redundant for modern GreenFeeds, such as setting up the GreenFeed processor files, because this is now done automatically for users.

Perhaps the most useful file once you have the GF operating, is the 'Greenfeed Instructions Cheat Sheet', because this summarises many aspects of GF operation.

GREENFEED PHYSICAL OPERATION

Key points:

- GreenFeed will only operate (dispense pellets) to animals with a radio frequency ear tag (electronic id, NAIT, round button). It is compulsory to fit all new born calves with NAIT tags, but some older animals will not have them.
- Some animals will not use GreenFeed
- Training can increase GreenFeed use
- Cows do not seem to train cows; individuals make their own decisions
- The amount and frequency of pellet drop differs in pastoral grazing from indoor feeding
- Composition of pellets seems relatively unimportant
- It is important to regulate individual animal access to the unit to
  a. Encourage an even distribution of visits over 24 h, and
  b. prevent excessive use by individuals (which in turn affects the composition of their diet)
- Once animals have adapted to the GreenFeed, consensus suggests little will be gained in terms of measurement accuracy or precision by extending measurements beyond 2 weeks
- Acceptance that some animals will not use GreenFeed will affect trial design, and it is important to have sufficient animals to meet objectives
- A single GreenFeed can estimate methane from about 40 users, and as many as 100 cows if 50-60% use it, and visits are 1-2/cow/day.
- Positioning of GreenFeed in barns or pastures does not seem important from a cow perspective, but users should consider possible effects of crowding (e.g. if it was in a corner of a barn, or adjacent to a water trough) and the need to move it when cows are given new pasture
- Outdoor orientation is best facing into the prevailing wind (so the wind blows over the cows' head when she is using GF
- Substantial rutting of pasture can occur in wet conditions, but only on peaty soils.

GreenFeed setup with cattle

This section deals primarily with aspects not covered in GF manuals, obtainable from the c-lock website (Figs 5 and 6, ‘other’); especially operation at pasture.

GreenFeeds are always operated with a chute to ensure only one animal can access it at a time, and to prevent damage to the hood of the Greenfeed that could occur if two or individuals were fighting over access. However, the manufacturers recommend initial access (training) is undertaken by removing the chute, turning the fan off and allowing free access for up to a week. We do not dispute this recommendation, but wonder how important this process is. In a trial in Hamilton (2012) the highest number of cows visiting GF was on the first day (with the chute on). Even when the manufacturer’s recommendations have been followed, on occasions only 50% of cows were routine users. Cow use has been summarised in Hammond et al, 2016, and Waghorn et al. (2016).

Confined cattle in yards

In a pen situation, the GreenFeed may be placed outside of a pen (e.g. in a gate way) and a chute attached to the structure so that it can’t be moved by cattle. This is illustrated below (Fig 7), with a chute that was available (not specifically designed for GF). The chute is about 2.5 m long, and 0.8 m wide, so cattle could access the feeder easily. The GF can be powered from the mains, and the only challenge for the operator is to encourage all animals to visit the unit. A high usage may be more important than at grazing, especially if small numbers of animals are involved

Figure 7. A chute restricting access to GreenFeed, at AgResearch 2013

Grazing trials

Grazing trials require a more complex management of GF than indoor trials, with frequent moving, possible rutting of paddocks, risks of water affecting either air flow or pellet drop (if water gets into the system), the need to maintain power supply and internet connectivity, and greater challenges undertaking CO_2 calibrations in the field. Several trials have been undertaken in New Zealand with GreenFeeds with dairy cows grazing pasture; one of about 35 days (Garnett, 2012; Waghorn et al., 2013), and another for four x 20 day periods over about 7 months (Waghorn et al., 2016), and more recently for 20-50 days duration with cattle fed either kale, fodder beet or pasture at Lincoln (draft report by Waghorn and Jonker submitted to SLMACC by Cecile deKlein, AgResearch, Invermay).

An early objective was to determine an optimal chute design, and the first trial showed a “sled” design was a suitable design (compared to one able to be dismantled), because it was worked well, was easy to move (towed behind GreenFeed) and was robust. The next trial resulted in shortening of chutes, from about 2.5 m to about 2 m in length, and as well as being towed between paddocks, the trailers are designed so a sled can sit across the front for road transport. When moving between paddocks, the collars used to attach GF to

the trailer are removed and the sled follows the GF between paddocks, towed by 1.2 m chains. When at its destination, the chute is pushed up to the GF and the two collars are reattached (Fig 8).

Figure 8. Chutes attached to GreenFeeds

The GF are moved with the cows, and moving (and replenishing fuel and feed is easiest achieved when cows are being milked. In some situations, when cows are strip-grazing a single paddock (am and pm breaks), the GF can be positioned close to new breaks, to reduce the need for moving. The GF should be within 20 m of feed being grazed to encourage use.

Other challenges include maintenance of power supply, but this is a much less of a challenge in models with generators. Implementation did involve some concerns, especially around frequent start/stop cycles, but most issues have been resolved by configuring the signal to turn on correctly. Data are available when logging onto the website that enables battery status to be viewed (e.g. Fig. 9), but users would be best to consult an electrician, or someone with prior experience prior to interfering with settings.

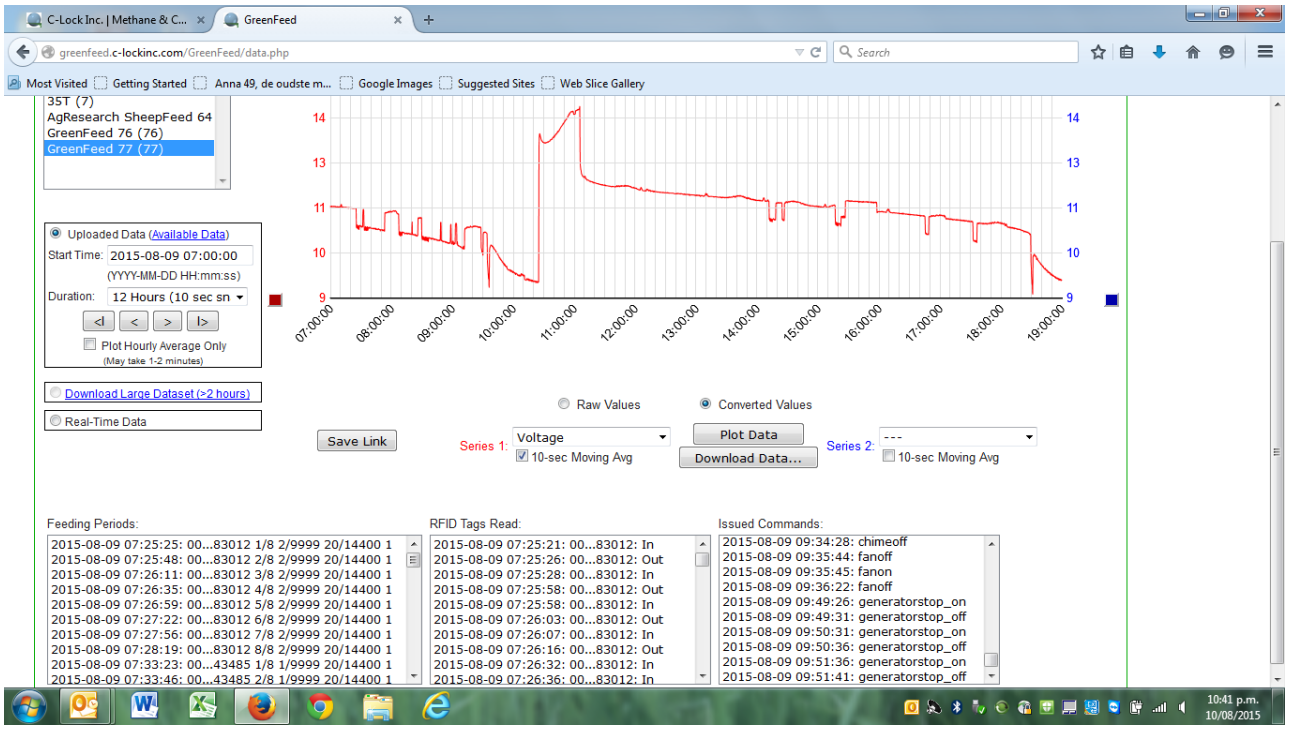


Figure 9 An example of battery voltage (red line) from GreenFeed 77 from 7 am on 9th August for 12 h, showing a few false starts followed by a decent charge at 10.30 am when the battery voltage was very low

In general, when you are new to GreenFeed, have a play to understand what you can measure/monitor, but don't change anything that is working OK!!

Air flow is an important component of GF operation and details of filter changing are provided below. Users will be alerted to reduced air flow by GF, but it is sensible to check the filters weekly and especially after rain. Filters are expensive and washable.

Feed blockages

On occasions feed does not drop into the tray, and this can be due to two main causes; wet pellets and bridging. Wet pellets are a lesser problem on current than previous models, but bridging does occur on occasions. This is when the pellets form a 'bridge above the dispensing mechanism so no further pellets are dropped. Testing can be done remotely by pressing the 'drop feed' button and checking on the camera, or at the GF by pressing the feed drop button (Fig. 10). If feed is not dropping, three pieces of equipment are needed to investigate and resolve the problem: a long stick (or most likely an electric

fence standard) to ‘break’ the bridge, a piece of stiff wire to poke up the outlet pipe that drops feed into the dish, and a soup ladle to scoop all the pellets out. The latter is a last resort, time consuming and you may need some place to put 50 kg pellets! It is usually drizzling or very windy when you have to do this.

In our experience, cattle rarely cause damage to GF, and all wires have been made inaccessible on current models. Currently the trailer is protected by barriers, to prevent access to the tool box and generator.

Trial design

Trial design will be driven by experimental objectives, and the implementation of GF will be driven by the objectives, in conjunction with constrains that will differ between sites and situations. An overview of GF operation and implementation with cattle in a number of environments has been published by Hammond et al. (2016) and details of cow use in a pastoral setting in New Zealand have been summarised by Waghorn et al., 2016. These papers demonstrate a range in the percentage of cows visiting a GF (often 50-70% at grazing) and visiting cows do so between 1-3.5 times/day at pasture. These factors will affect the number of cows that can be monitored by a single unit, but reasons for variations in cows using GF and visits/day are not understood.

The duration of trials are also affected by the experimental objective, but a minimum of 16-20 days has been suggested (Waghorn et al., 2016), following a period of acclimation when first introduced. The low incidence of users in all pastoral trials in New Zealand (Garnett, 2012; Waghorn et al, 2016) and elsewhere (Hammond et al., 2016) has implications for screening and ranking cattle. Individuals have to visit to be evaluated, and any bias in visitation times could affect ranking, for example visits at night are likely to result in lower methane estimates than visits around noon and there may be a need to weight data for accurate comparisons (Hammond et al., 2016).

GREENFEED CONTROLS AND MAINTENANCE

GreenFeed is able to estimate gas emissions from individual animals, and to do this it needs to know

1. Which animal is visiting, how long it is ‘in the unit’ for and when (time, day, etc)
2. The concentration of gases when the animal is present as well as background values
3. The flow rate of air and the gas capture (% of emissions)

So, the operator needs to ensure that all these functions are operational and the calibrations are accurate. Animal identification requires NAIT (button) ear tags, and the operational instructions (GreenFeed manual) show how to regulate access to prevent excessive visits and how to monitor animal usage. Gas concentrations are validated via auto calibration, and manual CO_2 recoveries, and airflow is measured, with alerts sent (email) should flow rates diminish. Operators can even set the criteria when email alerts are sent.

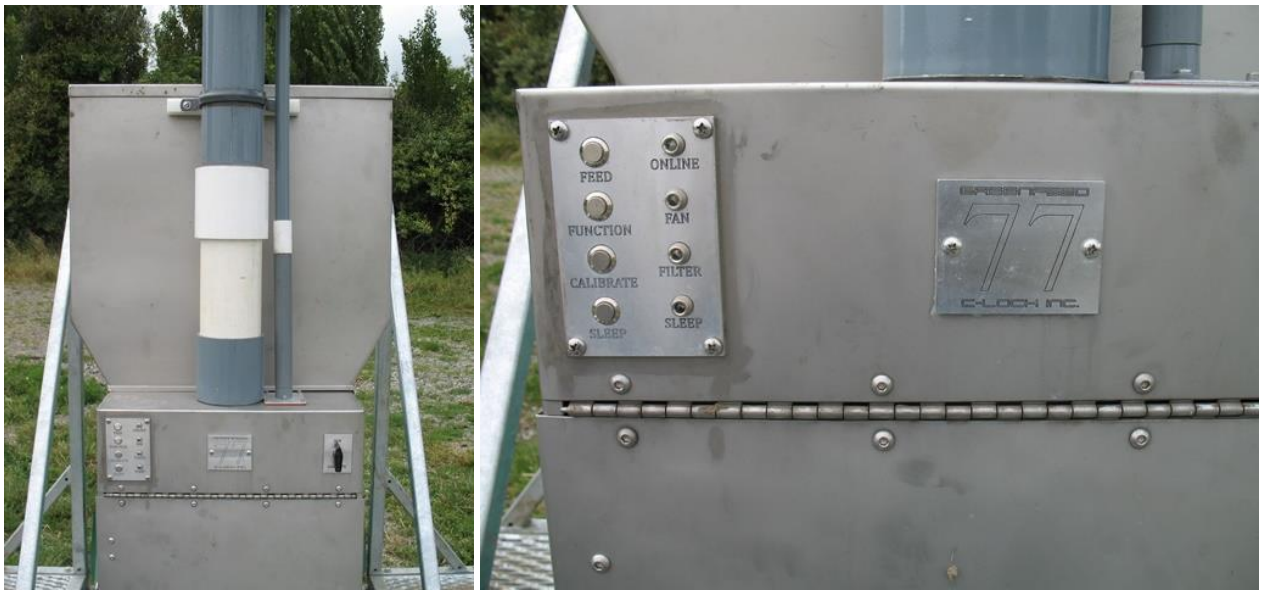


Figure 10. The chimney and control panel on GF 77 showing the four control buttons, of which feed drop and sleep are most used, as well as lights to indicate operation.

Most control is achieved via the website, but daily visits to GF are also required for topping up pellets, fuel for generators and moving the units to new pasture. Each GF has a control panel (Figure 10) that provides both an instant guide to its status, and provides an opportunity for doing things without web access.

Control panel

An easy way to understand the controls on Greenfeed is via the “cheat sheet”, which shows:

1. That it is out of date! The sheet says the GF has 3 lights, but in reality it has 4 lights, and indicate if it is online, the fan is going (very important for measurements and calibration), if the air flow through the filter is adequate, or if it is in ‘sleep’ mode (partial shutdown for moving)
2. The lights are either on, or blinking and the pattern of blinking can indicate different problems, but these are usually best remedied remotely. If the lights are on,
    a. There is internet connectivity
    b. the fan is on,
    c. the filter needs cleaning (air flow is slow),
    d. the unit is in in sleep mode and not operational
3. there are also 4 buttons, and those used most frequently are:
    a. the feed drop (press for a few seconds) to check for blockages,
    b. the sleep mode button for moving between paddocks, although this is unnecessary for short moves if you move it carefully. Sleep mode turns the fan off, and it is essential to turn it back on!
    c. The GF units are auto-calibrated, so the button is redundant on the new models.
    d. The function button is for technical use only and should not be used

Powering up and down

There are two options to power the GreenFeed.

1. The 110/220 volt AC power converter (in the tool box) that plugs into the bottom plug in the awkward grey box on the right side of the feeder (Fig. 11, left).

2. The lead from the generator, that plugs into the same socket in the box.

Figure 11, sockets and switches

GreenFeed operates from the batteries in the tool box, and the generator charges the batteries. The generators are the only option for operating GF in the field and the wiring from GF to the batteries is enclosed and protected from cattle; only when indoors would a power converter be used to operate GF.

Figure 11 shows several switches; the middle one is a safety requirement to meet New Zealand regulations to isolate the mains (240v) output from the generators, and the red switch (Fig.11, right) enables GF to be isolated from the power supply. Turn this off when you are playing with the electrics, because it protects delicate electronics from power surges, (e.g. example manual generator start) and protects you from the GF machine unexpectedly starting the generator".

Figure 12. Generator controls and oil filler.

If the generator is started manually and then reconfigured to the auto start, by stopping the generator, turning the generator key to ‘on’ (Fig 12), the red switch (Fig 11, right) will need to be turned on to activate the GF.

Powering down the Feeder for storage or moving

1. Press and hold the “SLEEP” button for 3 seconds then release it. The “SLEEP” light will blink. This allows the feeder to upload any recent data before the unit is powered down. The fan will shut down and data will begin uploading. Once the data is finished uploading, the “SLEEP” light will stop blinking and it is safe to continue shutting down the feeder.
2. Turn the red switch off in the tool box.
3. For long trips, remove the anemometer and wind vane, and lower the bracket using the 11 mm spanner that is not in the tool kit.
4. Turn the valves off on the calibration gas bottles in the tool box when the unit is not being used for a week or more.
5. Turn them on again when you want to use GF!!

Sleep mode allows the user to reduce the power consumption of the feeder if it will not be used for a short period of time (overnight or for a weekend, for example), but enables an immediate power-up. In sleep mode GF will stop collecting data and upload any unsaved data to the central C-Lock server, which may take up to two minutes. The fan, sample pump, feeder (pellet drop), gas calibration and RFID reader are turned off, to reduce power consumption.

If the feeder is powered down without first being put to sleep, then any data that have not been uploaded will upload the next time the feeder is powered on again. Data are not lost and the GreenFeed unit will not be harmed if it is turned off without being put to sleep first, however any resident data will not be accessible until the next time the GreenFeed unit is powered on. It is preferable to use the sleep mode setting before shutting GF down.

Powering up Greenfeed

To re-activate the unit (wake up the unit), from sleep mode, press the “SLEEP” button for 3 seconds. The start-up process takes only about 20 seconds because the electronics have been powered whilst asleep, and the generator will not need to run if the batteries are charged. From a complete shut-down, powering up will activate the fan after about 20 seconds, but 10 minutes are required for the methane and CO_2 sensors to warm up during which time the tracers may activate. It is recommended that a calibration be undertaken if the feeder has been powered down for more than two days.

Cleaning the air filter

The air filter should be cleaned every two weeks or when it is wet and any time the “filter” light is on, indicating a low air flow. Open the air filter box lid by loosening the latches on the right side of the air filter box (Fig 13).

Figure 13. The air filter in place and removed for cleaning/replacement

To clean the filter, put the system in sleep mode and wait for fan to turn off. Then loosen the clamp at the top and pulling the filter down. Put the clamp on a clean air filter, insert over the pipe, tighten the clamp, close the lid and turn off sleep mode.

The filter is cleaned by

1. Tapping the black rubber end lightly against a hard surface.
2. Rinse with water, inside and out, and drying thoroughly before reinstalling.

CALIBRATIONS

There are three types of calibrations (or recoveries), two automated and one manual (CO_2).

1. The **propane** that is emitted occasionally through the flexible pipe in the place where the cow puts her head, and into the conduit leading to the sensors.
2. **Auto-calibrations** with span gas (CO_2 and methane)
3. Manual **CO_2 recovery**

The **propane** tracer system comprises a replaceable propane container, filter, and a regulator to control the pressure with a critical orifice and solenoid valves to control propane release rate. A scrubber removes the sulphur smell and it is released

1. From a nozzle hanging down inside the feeder where the cow accesses pellets ("Feeder Tracer" or "Dish Tracer.")
2. Inside of the collection pipe leading to the sensors, where 100 percent of the tracer is always captured. This is called the "Pipe Tracer" or "Standard Tracer."

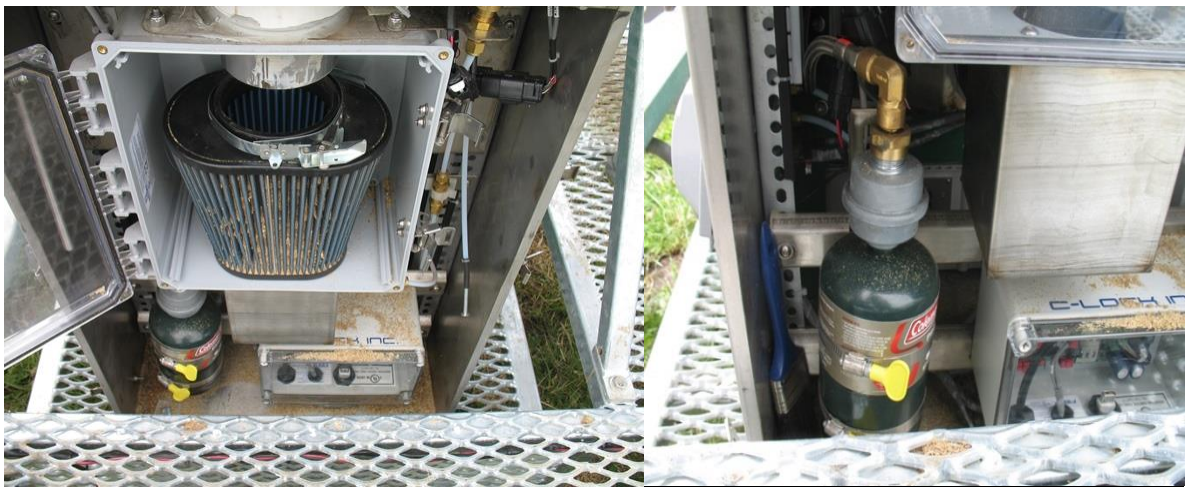


Figure 14 showing the location of the propane cylinder, relative to the air filter.

The propane tank is replaced by loosening the yellow thumb screws (Fig 14). There do not appear to be any gauges to indicate when propane is running out, but when replacing it the filter (above the tank) should remain in place.

Auto-calibrations with span gas is from bottles inside the tool box on the front of the trailer (Fig 15). These bottles contain either nitrogen or SPAN gas; 1000 ppm (0.1%) methane and 10000 ppm (1.0%) CO2. These gases are used to calibrate the GF; they are expensive (~$1500), which is why the valves are shut off when not in use.

Figure 15 Bottles containing nitrogen and SPAN gas used for GreenFeed calibration

The purpose of the **CH_4 and CO_2 concentration calibrations** is to compare the sensor's response when a known concentration of gas is placed into the sensor. The sensors in GreenFeed can "drift" overtime, so for optimal accuracy, it is important to periodically perform calibrations of the sensors. The Greenfeeds owned by AgResearch have an auto-calibration capability, so operators do not need to undertake routine calibrations. These are performed according to preset criteria in the GF. Auto- calibration is to reduce the amount of work for the operators and to maximise accuracy of the measurements, and is especially useful when operating GF in windy conditions (foil bags of calibration gas tended to blow away).

C-lock sent us a power point presentation about auto-calibration (appendix), and the relevant bits (Fig 16) are:

- The auto-calibration is controlled through the GreenFeed interface
- In order to have autonomous operation the standard tanks will need to be left on

- From the Feeders page, select the unit, then click the “Configure” tab.
- Scroll down to “Times to auto-calibrate system” and enter the time to run the daily auto-calibration. (Enter the time in 24 hour HH:MM:SS format)
- To test the Auto-Calibration system, click “Auto-Calibrate”
- Wait 3 minutes, then view the CH_4 and CO_2 in the “Data” page

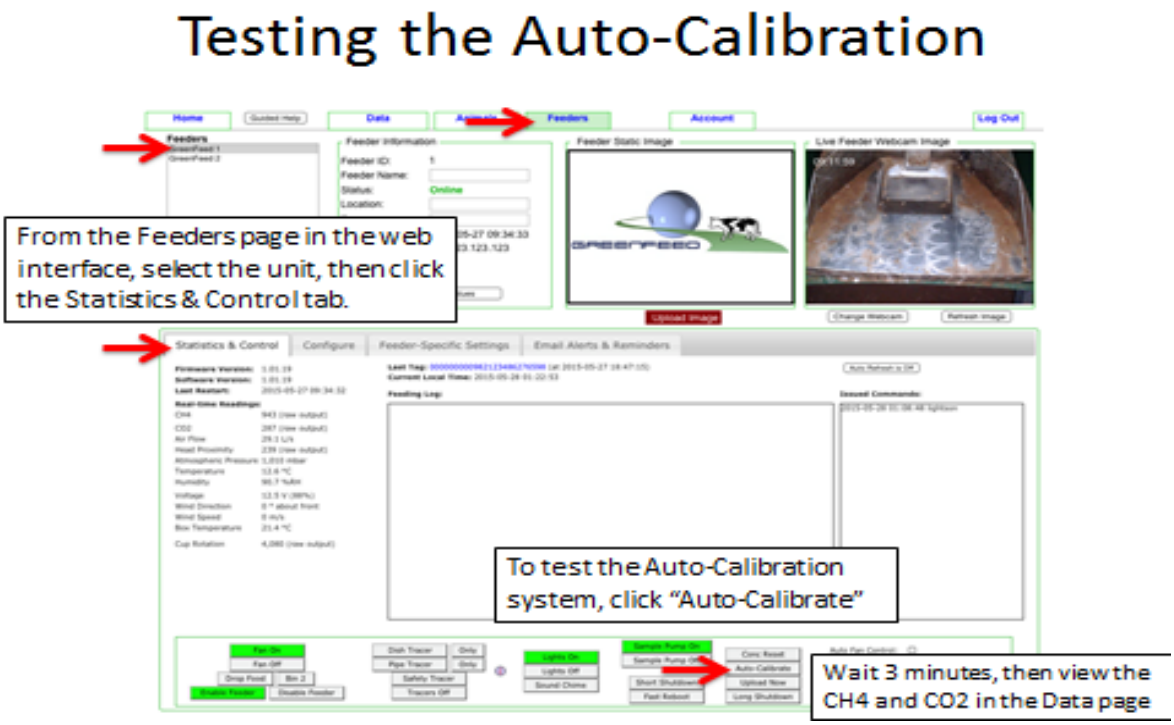
To configure the auto-calibration time

- From the “Feeders” page, select the unit, then click the “Configure” tab.
- Scroll down to “Times to auto-calibrate system” and enter the time to run the daily auto-calibration. (Enter the time in 24 hour HH:MM:SS format)
- Click “Save Settings”

These settings are indicated on the next two pages in a fairly blurry format.

Manual methane and CO_2 calibration

On the front of the GreenFeed unit, on the right is a switch that will enable you to do manual calibrations. This is unnecessary, but also fairly easy, requiring access to the gases. However, the bottles are plumbed in to the auto system, so the manual system is irrelevant, and is not detailed here.



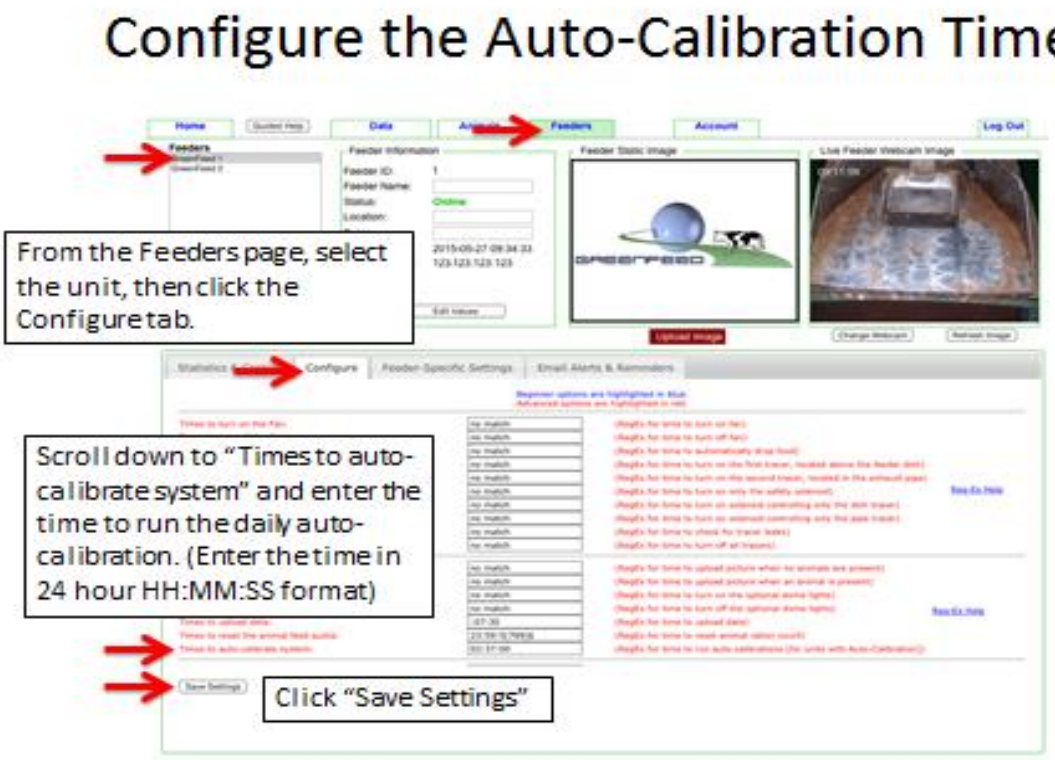


Figure 16 Depiction of auto calibration settings (Appendix)

Manual CO_2 Recovery

A CO_2 recovery test is carried out every 2 weeks during GF operation to determine sensor calibration, by releasing a known quantity of CO_2 through a hole in the food dish (the one with a washer welded around it; Fig 18) and comparing the actual amount released with GF calculations. The amount released, and the time (duration) of release is measured, to ensure that the volumetric flow rate is accurate and that the concentration sensors are using the correct calibration factor. This is a manual task, and shouldn't be hard, but can be fought with problems. To do this, the fan must be running (not on auto) and you will need

- The nozzle system (tighten the joint mid-way along the pipe
- CO_2 cylinders (paint-ball type)
- Scales able to weigh to 0.1 g; electronic kitchen scales can be ideal.
- A timer – e.g. phone (measure to nearest second), and it should align with true time because you need the weights of CO_2 to match times the sensors measure it.
- Warm water and a towel (if ice forms on the valve – messes up the weights a bit!)
- Pen and paper
- A lot of luck – don't know why, but some people find this difficult, but really it is pretty simple. This is probably easiest with two people.

Figure 17. The CO_2 canister connected to the valve and dispensing pipe, and being weighed. The button tag tells GreenFeed that the CO_2 release is a calibration.

Prior to calibrations, ensure that the valve on the nozzle system is off; screw the CO_2 cylinder into the connector, weigh it, and leave on scale for a minute (for the first time) to ensure there are no leaks (Fig 17). You are now ready to go

From now on, do not let any animals get near GreenFeed. You are an animal, so don't breathe into GF either!

1. Weigh the CO_2 cylinder plus release system. Record this as the initial weight and write it down.
2. Put this into the feeder dish and poke the nozzle through the hole in the back

Figure 18. The probe on the gas bottle is poked through a hole in the back of the feed dish for CO_2 release

3. Turn on the valve to release the CO_2 and record the time (to the nearest second), and stand away from the GreenFeed. Let the gas flow for ~3 minutes. Write the time you turned the valve.
4. Turn the valve off after about 3 minutes and record the time. Don't breath into the GreenFeed.
5. Remove the system with cylinder attached and weigh it. Write the weight and time on the sheet
6. Place the CO_2 cylinder in a bucket of warm water and wait for it to warm up (may take a few minutes). Keep the valve out of the water.
7. Remove the cylinder from the water and dry it. Weigh it after 2-3 minutes
8. Repeat steps *1 through 7*; 5-10 times. Marking the new start time, initial and final weights for each release. I would stop after 6-8 of these or you could go nuts with boredom.

A 90g CO_2 tank will provide about 3 releases so you will need to use multiple tanks. When a tank is empty, weigh the empty tank and continue with a new tank. If you only get 2 minutes from the last run, that is ok, just record the time and weight. Wait 3 minutes after the last CO2 release before allowing animals to gain access to GreenFeed again.

Once a CO_2 Recovery has been performed, the values must be entered into the GreenFeed online interface before the sensors can be verified working correctly. See "Recording a CO_2 Recovery" in the instruction manual

DATA FLOW is as follows:

1) A computer located inside GreenFeed stores the real-time data then uploads it to the C- Lock server every hour.
2) Data uploaded to the C-lock server is archived
3) Data on their server is processed daily to estimate animal emissions
4) Users can download real-time data from GF, or raw data, or processed data from the C-lock server. Historical data remains available and can be downloaded using the graphical user interface.

Processed data with emissions fluxes is in Excel spreadsheets are accessible to users.

GreenFeed units 76 and 77 are accessible via http://greenfeed.c-lockinc.com and log in using the username 'lovejoy' and the password. The c-lock Home Page provides an overview of options, and users must click the links to gain experience that will enable use of the GreenFeed system. New users, just be brave –Try it! Each page has a "Guided Help" option, and it is most unlikely that trying the system will compromise your data, but care and caution should be exercised when configuring/adjusting settings on the units.

Finally, tips for using the GF interface.

1. Be patient; things sometimes take a few seconds to load
2. When you make changes to settings, you need to click 'apply' – or changes won't be saved (e.g. in regulating frequency of animal use, or pellet drops.
3. The dates are American and very annoying, e.g. 05/04/2016 is actually May!
4. Make sure you identify the GF unit you are adjusting/interrogating; every page and every time
5. Screen settings often need to be refreshed frequently, for example if you are looking at one function (e.g. battery voltage) over a defined period, then want to check wind speed, you will need to reenter the times and dates again.
6. When really frustrated, call someone who has used GF, and if necessary contact c-lock; they can be quite helpful.

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APPENDIX Autocalibration instructions Supplied by c-lock

Needed Equipment

- Demand Flow Regulators (supplied)
- Zero and Span gas
- Tank stems (attaches the regulator to the tank user supplied)
- Teflon tubing (supplied)
- 9/16" end wrench
- Thread sealant

Place the Tanks

- Place the standard tanks in a safe area where the tanks can be anchored, but within the tubing reach (about 4 meters with the provided tubing)
- For trailer installation the tanks may be laid flat but still need to be secured

An example of trailer mounted tanks

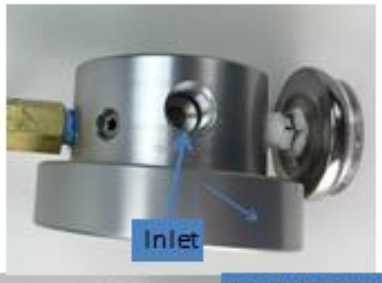
Route the Tubing

- Connect the regulators to the standard tanks
- Connect one end of the tubing to the compression fitting on the regulator
- Route the tubing so it is out of the way of foot traffic and out of the reach of any animals
- Connect the tubing to the GreenFeed taking note to run the correct line to the correct port
- Double check that the compression fittings are all tight (the auto-cal system will not work with vacuum leaks)

GreenFeed line connection

Attached Stems to Regulators

- Using appropriate thread sealant (PTFE Tape is recommended for application instructions go here: http://norcal.swagelok.com/blog/bid/88017/Skill-Applying-PTFE-tape-to-tapered-pipe-threads) screw the stems into the inlet port on the regulator be sure to support the regulator body, do not apply torque to the attached fittings (be aware not to get Teflon tape in the regulators)
- Attached regulators to the standard tanks and pressurize the regulators
- Check for leaks using a soap and water solution (the solution will bubble at any leak source)
- Once the regulators are leak checked turn off the standard tanks



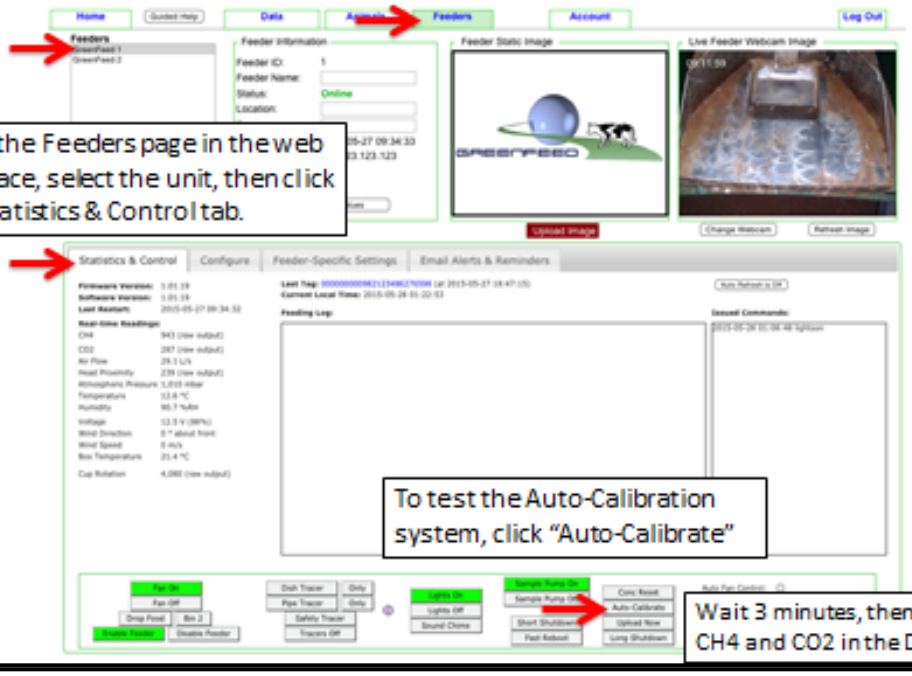
Bleed Down Test

- We recommend a bleed down test to verify all equipment is working properly
- Once the auto-cal is hooked up to the GreenFeed pressurize each regulator and mark the position of the needle on each gauge
- Verify that Auto-cal is off in the GreenFeed interface
- Turn each tank off
- Check to make sure that the needle has not moved after 30 minutes

Run the Auto-Calibration

- The auto-calibration is controlled through the GreenFeed interface
- In order to have a full autonomous operation the standard tanks will need to be left on

Testing the Auto-Calibration



Configure the Auto-Calibration Time