# Instruction Manual

Version 5.0. August 2011

# TANDEM Family of Gas Analysers


TANDEM
Gas Analyser

TANDEM *PRO*
Gas Analyser

TANDEMMULTIPLEX
Gas Analyser

Magellan | Instruments

# Contents

# 1. General Introduction

**SAFETY**

Customers who use glass or plastic vessels must be aware that their vessels may not be designed to handle a build-up of pressure inside. You will be handling compressed gas in many cases and so must be careful of potential explosions. Depending on configuration, the Tandem TGA and Tandem *PRO* may exert a back-pressure of up to 0.2 bar / 3 psi when used on small vessels.

You should only attach low pressure gases (< 0.2 bar / 3 psi) to the Tandem. Use a pressure regulator on your gas bottles or central gas supply to ensure this low pressure.

If you live in an area with uncertain electricity supplies, possibly with spikes, you should protect your Tandem just like other equipment with an uninterruptible power supply (UPS).

You should not let media or water enter the Tandem, this is not covered by our guarantee. Use a foam trap if you are uncertain. Minor water intrusion may also damage the Tandem and it should be emptied or dried before continuing to use the unit. If it malfunctions, you will probably need to service the unit.

## 1.1 Background

This equipment has been designed and built to exacting standards and should users find any quality or functional problems, they should contact Magellan Instruments immediately by email: sales@magellaninstruments.com or your local supplier. The gas sensors within the Tandem systems are designed to run continuously but calibration should be checked on a regular basis (once a month or more).

## 1.2 Electrical supply

Ensure that the power switch (110V / 240V) is correctly assigned for your country on the Tandem back panel before plugging in. If you will be using the Tandem in an area which may experience electricity supply problems or power surges, we strongly recommend you take appropriate precautionary measures, e.g. by using a UPS.

## 1.3 Fermenter Inlet Gas Supply

If you use air from your location as a source for the fermenter air supply, you should be aware that the level of O2 and CO2 in ambient air varies both by location and sometimes to a small extent within one location by time. Therefore it is important to occasionally measure the air inlet supply using the Tandem to check it is constant. If you use the Tandem Multiplex, you can set up one of the gas inlet lines to permanently measure the inlet gas composition of your fermenter – particularly if you use mixed gas inflows (solenoids & massflows for O2 supplementation are not as accurate as the Tandem).

The gas-flow should be filtered and ideally dry. If you have a high air flow (1vvm or more), you may wish to consider using a drying system. If you are performing precise on-line calculations, removal of humidity will provide better results. We do not provide drying systems, but users have reported good results with systems from both drierite.com and the Supreme Model 120 from geniefilters.com.

## 1.4 Calibration Gases

The Tandem gas analysers require calibration gases to be available in the approximate range to be used. Two gases are sufficient to provide a calibration curve, in a similar way to a DO or pH probe two point calibration. These gases are often supplied in bottles with a mixed concentration such as 3% CO2, 18% O2 and 79% N2 (BOC recipe 281700). You will also need a second positive concentration for CO2 & O2 (e.g. 8% CO2, 10% O2). Do not use Nitrogen as this will introduce an offset since the sensors are not linear below 0.1% concentrations. Air also **cannot** be used as a calibration gas. Two positive points will be more accurate than a zero and a positive point. An explanation of calibration and associated topics can be found in section 5 (Calibration).

# 2. Unpacking

Please choose the appropriate section below according to what you have ordered:

## 2.1 ALL SYSTEMS

There will be the following items within the box irrelevant of which system you have ordered:

- a power lead for your country
- this Manual
- a calibration certificate

In addition, there will be the following items within the box dependent on which system you ordered:

### 2.1.1 Tandem TGA

There will be the following additional items within the box:

- the Tandem gas analyser
- a signal lead for V/mA (if ordered)

### 2.1.2 Tandem PRO

There will be the following additional items within the box:

- the Tandem PRO gas analyser
- a signal lead for V/mA (if ordered)
- an RS232 signal lead (if ordered)

### 2.1.3 Tandem Multiplex

There will be the following additional items within the box:

- the Tandem Multiplex gas analyser
- one or more signal leads for V/mA (if ordered)
- an RS232 signal lead (if ordered)

## 2.2 Signal Lead

There are several different types of signal lead for connecting the Tandems to the various instrumentation and computer systems available. They are:

Bare wires (mA and V)
Braun/Sartorius Biostat A+/B/C
RS232

Later in this manual, you will find out how to connect the Tandem to your particular instrumentation and bioreactor.

# 3. Installation

### 3.1 Tandem TGA and Tandem PRO

The Tandem can be placed anywhere convenient for the user. In a laboratory environment, this is often on top of the main instrumentation controller unit, beside the bioreactor. In a manufacturing environment, it may be placed on a shelf or cabinet unit near the top of the reactor, **after the gas outlet pressure control valve**.

Normally, the Tandem, once installed, is not moved, so the connections have been placed on the rear of the system for tidiness. If you plan on using the Tandem as a mobile calibration or verification unit, then a wheeled trolley with laptop PC is ideal.

### 3.2 Tandem Multiplex

The Mutliplex system may be placed anywhere convenient in the fermenter room, or even in a separate room if required. It can be mounted on the wall, or placed on the bench or side table. You need access to each side for the electricity, signal cables and fermenter line attachments, 30cm gap is sufficient for each side.

The further from the fermenters it is placed, the longer it takes for gas to reach it and so slows down the measurement intervals. The gas lines must be attached to the exhaust fermenter flow at the last possible point, and **after the gas outlet pressure control valve**.

If using the RS232 communication signal, it can reliably be carried 5m, occasionally longer. Therefore, the computer or controller receiving the data should be nearby. You can use RS232 boosters, or otherwise please use the mA signal leads.

### 3.3 Exhaust/Vent Gas Supply

The Tandem requires a dry stream of gas, clean of particulates, at a volume of between 0.05-1 litre per minute (50ml-1000ml / min). The exact flow is not important and a varying flow in this range will not affect sensor performance. This flow may be provided by splitting the exhaust gas after the vent filter into two streams, by use of a plastic T piece in the laboratory, or by a valve and/or small ‘T’ pipe piece in larger reactors. The side branch should be **significantly smaller in diameter than the main exhaust line**.

For the Tandem TGA, a slight restriction using a Hoffman clip or gate clamp on the free branch will ensure flow through the Tandem that can be regulated using the rotameter.

For the PRO and Multiplex, the internal gas pump in conjunction with the rotameter on the front allows a sufficient flow of gas to be taken out from the main bioreactor exhaust stream without any additional restrictions on the main bioreactor piping system. The pump may also be switched off if preferred.

A good condenser and a standard 0.2 micron filter on the exit line from the reactor will normally be enough to remove water vapour. However, users should bear in mind that water vapour can deposit on the sensors themselves (depending on air temperature) and this may affect their response times. Therefore, if the condenser is poor, or if the fermenter gas flow is over 1 vvm (1 vessel volume per minute), efforts should be made to dry the gas.

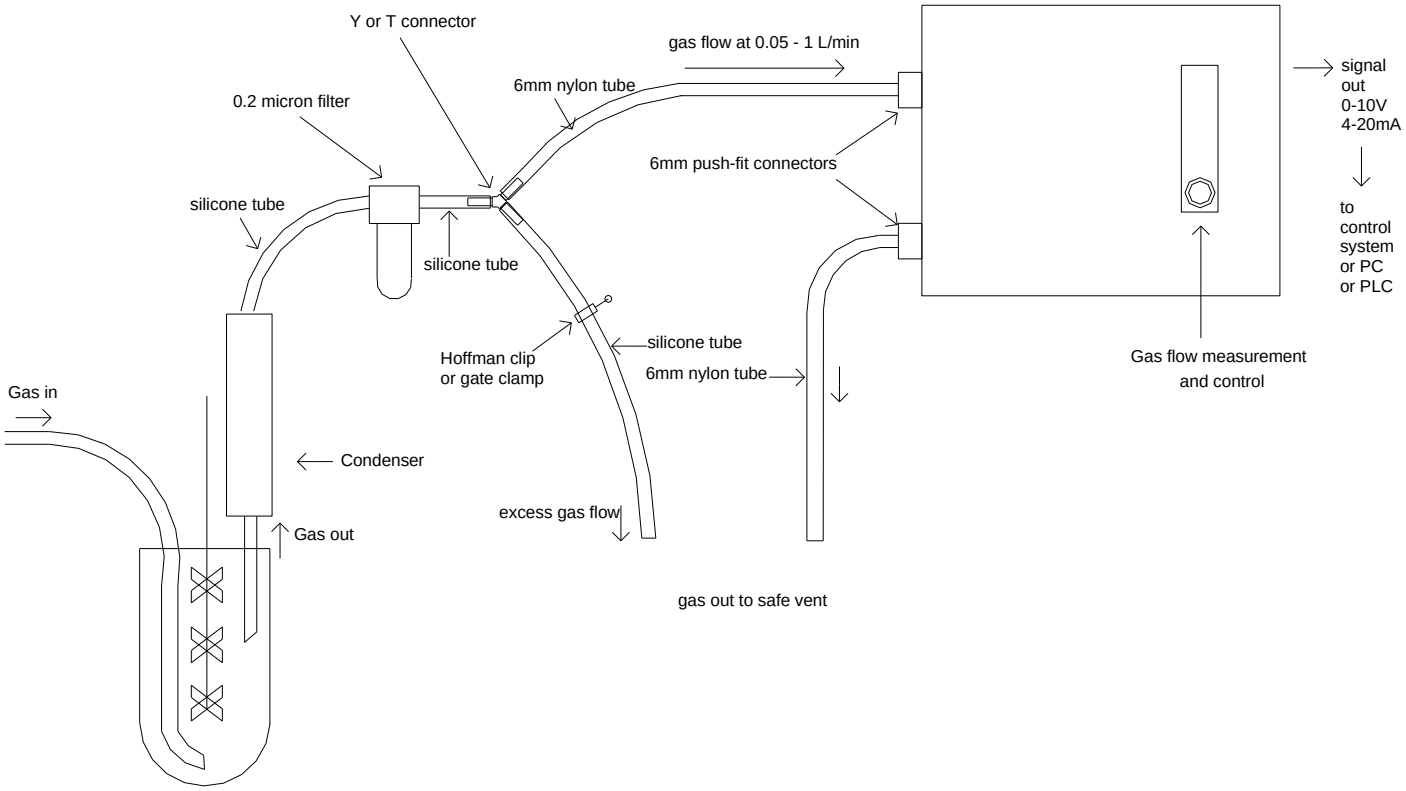
If you plan to use the Tandem to perform precise on-line calculations (e.g. on-line mass balancing), then a drying agent should be used to remove water vapour – heating the lines to avoid condensation is not sufficient. We do not provide drying systems, but users have reported good results with both drierite.com and Supreme Model 120 from geniefilters.com

### 3.4 Tubing

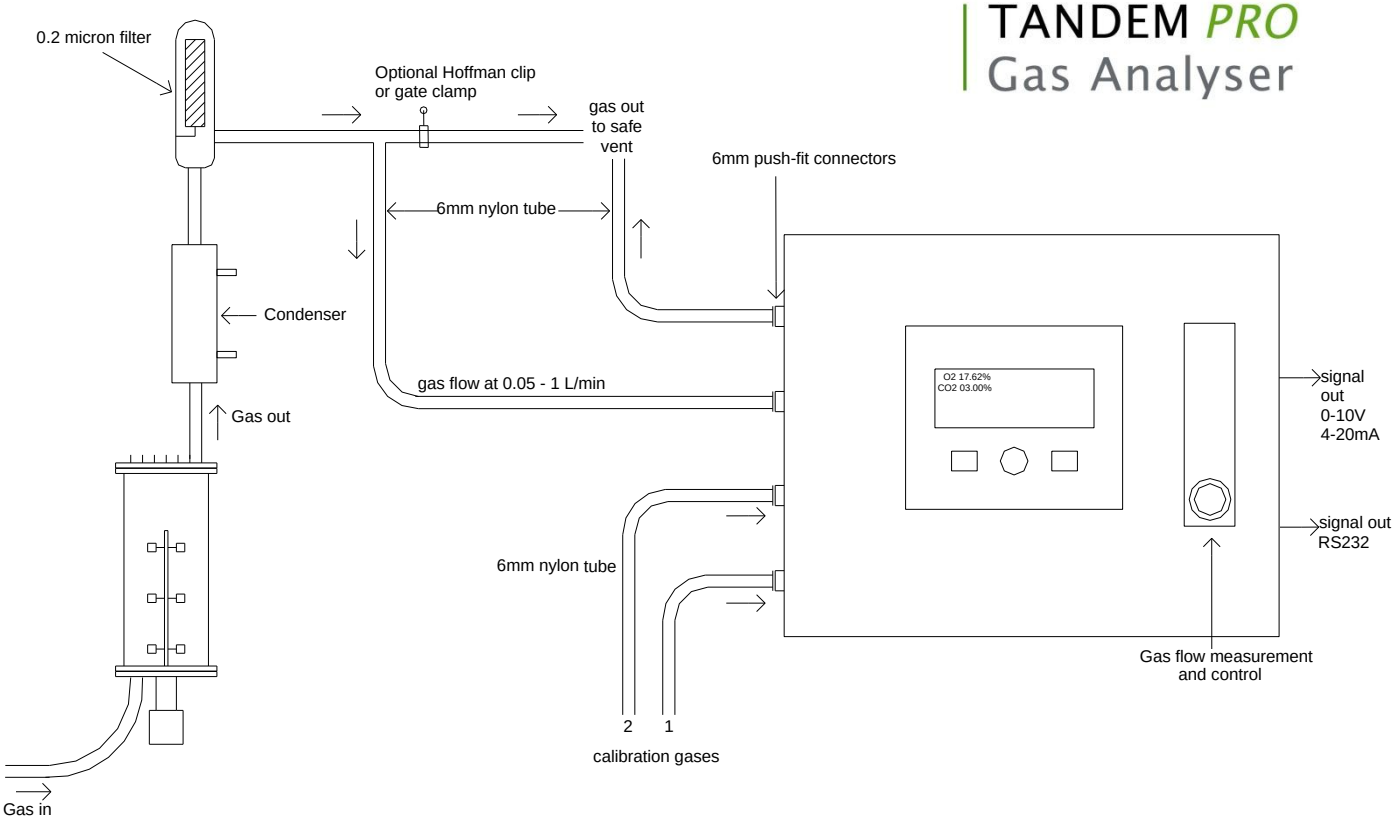
All Tandem systems use the same push fit Legris-type connectors for gas inlet and outlet which requires 6mm nylon tubing. You may use other tubing besides 6mm nylon between the bioreactor and the Tandem analyser, and this will not affect the sensors directly, however users are reminded of that silicone tubing is semi-permeable and so should be avoided for long distances. A long distance to the fermenter and/or a high internal tubing diameter, will mean a long time before the gas reaches the sensor.

### 3.5 Schematic Set Up

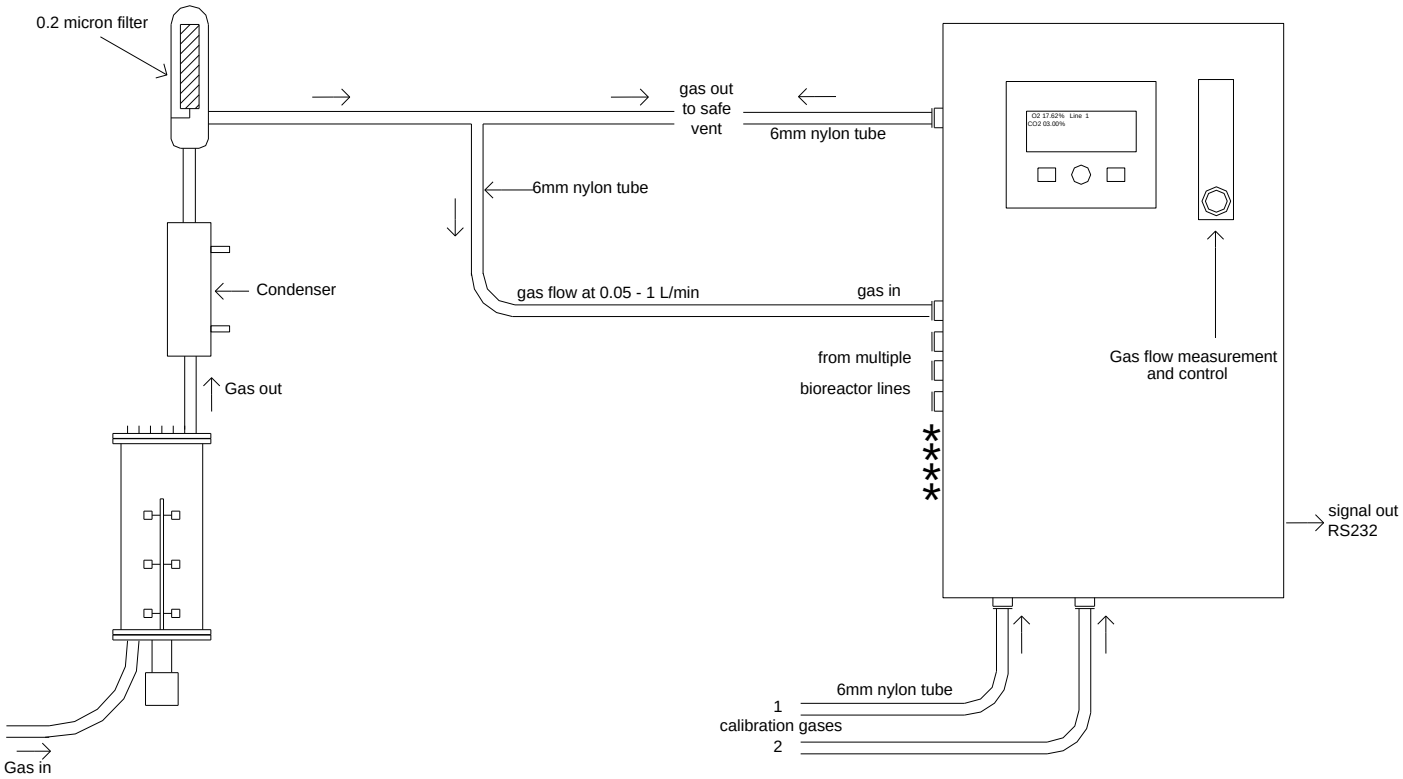
TANDEM
Gas Analyser




TANDEM *PRO*
Gas Analyser



TANDEMMULTIPLEX
Gas Analyser



### 3.6 Signal Lead & Connection to Instrumentation

The Tandem has three methods to communicate with your bioreactor control software and instrumentation.

- 0-10V
- 4-20mA
- RS232

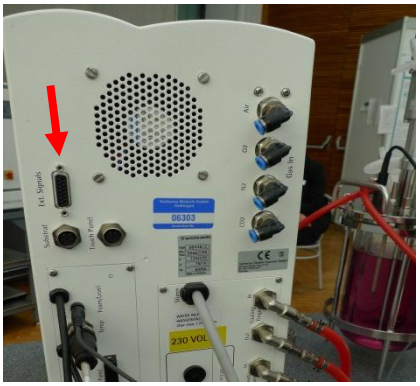
Almost every bioreactor has the facility to accept external 0-10V or 4-20mA signals in some fashion. You should check your bioreactor manual for instructions on how to do this. As a general guide, the following methods are the most common:

#### 3.6.1 Sartorius-Stedim

*Biostat A - Voltage*

You may use the special lead provided which plugs directly into the "External Signals" 15 pin D socket at the back of the instrumentation unit. The signal used is the voltage and this will be need configuring inside the PC software.

| | |
|---|---|
| Tandem Gas Analyser end | BLACK |
| Biostat Instrumentation end | YELLOW |



*BioStat B or C (old models) - Voltage*

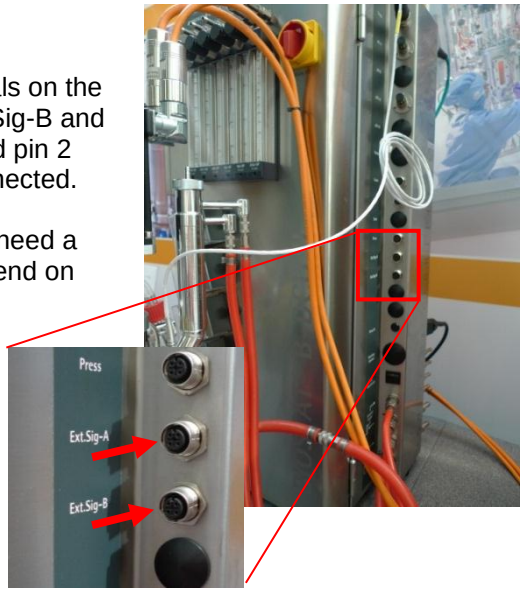
You may use the special lead provided which plugs directly into the "External Signals" 15 pin D socket just beside all your other sensors. This socket uses the 0-10 V signals which then appear in the main display window. These are called "Ext_1" and "Ext_2".

| | |
|---|---|
| Tandem Gas Analyser end | BLACK |
| Biostat Instrumentation end | YELLOW |

*BDCU II Model - Voltage*

The tower of the BDCU II has connections for external signals on the side of the fermenter. They are labelled Ext.Sig-A and Ext.Sig-B and use a 0-10V input for each. Pin 1 (top left) is the ground and pin 2 (top right) is the signal wire, the other pins should be unconnected.

In order to display the signals on the DCU screen, you may need a password to activate this level of functionality. This will depend on the type of system you originally paid for. You will need the help of your local representative in almost all cases.




*DCU 3 Model - MilliAmp*

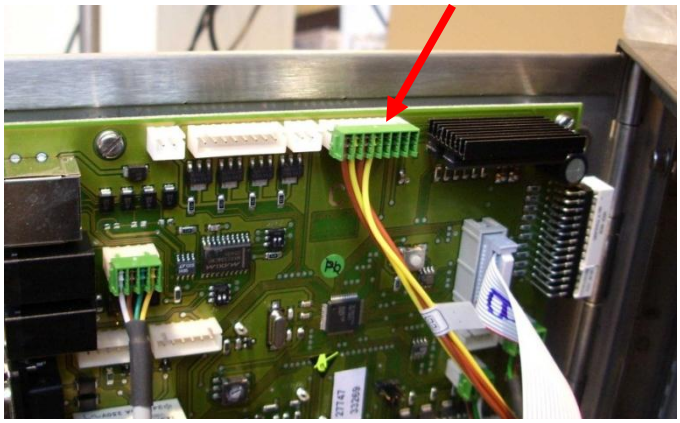
One of the first models (not shown) used a 25 pin D connector on the back of the instrumentation labelled "External Signals". You may find a connector already in place and that some of the pins are used.

### 3.6.2 Pierre Guerin

There are external signal inputs on almost every version of their lab/pilot and manufacturing reactors. The lab/pilot ones will either use a Lemo connector or, for the manufacturing versions, you will attach the bare wires directly on to a DIN rail inside the instrumentation cabinet. The signals are then picked up by the PC or PLC and will need labelling and configuring inside the software. We recommend you ask for the help of your local bioreactor representative.

### 3.6.3 Infors

Inside the instrumentation box, opened from the back, you will find a communications and control board. At the "top" of this board, there is a green screw terminal connector block. Most systems will have 4 or more of the connectors free, and the Tandem signals can plug into two of these, using the wires for the voltage signals. On the local controller, the signals will then be displayed as "Free1" and "Free2". You can re-label these using the Iris software package as Exit O2 and Exit CO2.



### 3.6.4 Applikon

Generally, there are limited options on these models to accept external signals into the local controller at the lab level. You will connect either to internal DIN rails or I/O cards inside the reactor, or directly to the supervisory software (BioXpert). The software runs on a PC and there is a preferred analogue to digital converter card. The cost is generally about euro1000-2000 for the card. If you have multiple massflow meters or controllers on your system, you may already have this card installed.

If you have a pilot or production fermenter, with a PLC or control cabinet, then there should be spare capacity inside the cabinet to attach new cables and signals into the system. Unfortunately, you will need the help of your local fermenter representative in almost all cases.

### 3.6.5 Finesse

*Models T300 & T500 - MilliAmp*

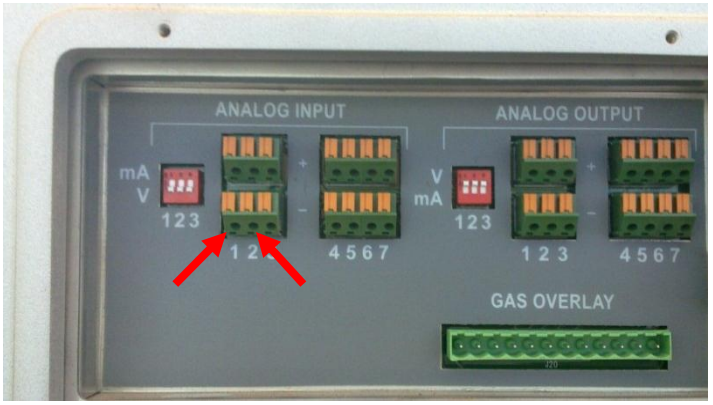
You will need to use two connectors which each take 4-20mA.

They are unlabelled on the T500 controller.

They are labelled AI 1 and AI 2 on the T300 controller and are located on the top of the instrumentation box.
In both cases, pin 1 is negative and pin 2 is positive for the signal.


### 3.6.6 New Brunswick

On the back or side panel of the BioFlo®/CelliGen® 310, 415, and 510 bench top controllers there are analog input & output terminals which allow the integration of both 4-20mA and 0-5V signals. Only the 4-20mA inputs should be used as the 0-5V will provide less resolution.




Some NBS controllers may require additional accessories such as an analog input/output module and BioCommand® SCADA software to facilitate proper integration.

### 3.6.7 Other

**Belach, BioTron, BioEngineering, New MBR, ABEC, Emerson/Delta V, Intellution and other systems**

Currently we have no reliable information on how to connect to these systems using the voltage and milliamp signal cables.

Generally, you should assume you will need to have an analogue to digital converter card compatible with the manufacturers' software. The price of this averages $2000.

If your system uses 0-5V or -5V to +5V, you can still use the Tandem outputs, but the signal will require modification. See the technical pages at the back for more information.

## 3.7 RS232 Output

The protocol used by the Tandem systems is described in the appendix. This protocol can be integrated into your own programme on a PC, or your bioreactor manufacturer can implement a driver to read the data. The information transmitted is not just the values, but also calibration and sensor health data, plus service history and user intervention information. This can be very helpful in preventative maintenance programmes, and accidental user error.

The following manufacturers' include the Tandem protocol in their software as standard:

- Pierre Guerin

If you use a fermenter from a manufacturer not on the above list, you can ask your manufacturer to implement the protocol for you. Some will charge for this service, others will not. Do not hesitate to ask your local Magellan representative for help with negotiating with your fermenter supplier to help you solve this problem.

# 4. Calibration

The Tandem sensors are made to high specifications of resolution, however, the sensors require calibration from time to time. The recommended minimum interval is every 3 months, and maybe even every batch if you are performing highly detailed comparative results.

Calibration of the Tandem works in the same way to a pH or DO calibration routine. Readings are taken at two previously known partial pressures (concentrations) for each gas and an offset and slope calculated.

You will therefore need two calibration gases. It is advisable to select gas concentrations that are appropriate to your process. For example, a mix of 3% CO2 and 10% O2 in one, and 7% CO2 and 18% O2 for the second. You need to order these gases from BOC, Air Liquide, Aga or your local gas supplier. ALWAYS ASK FOR A CERTIFICATE OF ANALYSIS – this shows the precise composition of the gases in the bottles you have bought, which is always different to what you ordered.

DO NOT USE air nor nitrogen as your calibration gases. Air is subject to variation in gas composition between rooms, pressures, temperatures etc. while the N2 acts as a zero point although the sensors are not linear below 0.1% concentration. By using air or nitrogen you will introduce small errors into your calibration.

### 4.1 General Procedure

a) Enter the calibration routine on your fermenter instrumentation or software if using a Tandem TGA, or choose the calibration option in the menu system of your PRO or Multiplex.
b) Pass the first calibration gas through your fermenter medium at working temperature. Adjust the exhaust gas line diameter or T-junction bleed, and the Tandem rotameter, to give 0.05-1L/min into the Tandem.
c) When the reading on the screen has stabilised (~2 mins) enter the percentages for $O_2$ and $CO_2$ from the certificate as the measurement values in the calibration routine.
d) Switch to the second calibration gas and pass this into the fermenter similarly.
e) When the reading has stabilised (~2 mins) enter the values shown on the certificate as the second calibration point.

This method will counter problems relating to water vapour errors. You can pass the gases directly into the Tandem if you do not have any significant issues with water evaporation.

### 4.2 Tandem *PRO* and Multiplex

The Tandem *PRO* and Multiplex have an option of manual calibration, similar to the standard Tandem, or automatic calibration which you set to occur regularly according to a schedule.

You will need enter the values from your calibration gas certificates into its memory. When a calibration occurs (manual or automatic), you do not need to re-enter the gas values, making the procedure quicker and simpler. See the menu system in section 5 for further information.

### 4.3 Derived / Calculated Variables

On-line or off-line, calculations based on the vent gas analysis can prove very useful to the user, for example respiratory quotient (RQ), growth rate (u), oxygen uptake rate (OUR), carbon dioxide evolution rate (CER), KLa etc. This can allow you to determine feeding strategies, metabolic changeover points, decision times for temperature or pH shifts etc.

You should be able to configure any reactor software to calculate most derived variables. It may be necessary to input the equations manually into the computer, whereas some manufacturers provide pre-programmed equations. Please examine your manual for precise instructions, or contact us for advice.

You cannot calculate these variables inside the Tandem itself.

# 5. Menu System

If you have a Tandem TGA, you may ignore this section.

The PRO and Multiplex versions use a microprocessor to enhance their functionality, and to automate several tasks. Also, the microprocessor checks on the health of the sensors and can note any user changes to the system, making it more appropriate to use in a GMP environment.

## 5.1 Button Descriptions

Each menu is described below. There are 3 buttons used to navigate and modify the settings on the Tandems: rectangle left, round middle, rectangle right. The general function of these buttons is:

| Button | Description of action | Label on screen |
|---|---|---|
| LEFT: | Choose a detailed menu to enter | Enter |
| | Choose to change a number | Change |
| | Increment a number | Inc |
| | Turn on/off a function | On/Off |
| MIDDLE: | Go to next menu in the list | Next |
| | OK, accept current values | OK |
| RIGHT: | Scroll for extra lines in menu | > or < |
| | Move to next number to change | > |
| | Escape back to main menu with no changes | Esc |

## 5.2 Menu Tree

0 - Initialization
1 - Main
2 - Calibration
- 3 - Calibration gases
  - 4-7 Change gases
- 8 - Auto Calibration
  - 9 - Auto Cal on/off
- 10 - Manual Calibration
  - 11-14 Perform Manual Cal

15 - Set Up
- 16 - Pump on/off
- **17 - Change RS232 Status (multiplex only)**
- **18 - Change lines used (multiplex only)**
- **19 - Change line timing (multiplex only)**
- 33 - Return to Factory Settings
  - 34 - Confirm factory settings

20 - Service Menu
- 21 - Change time

### 5.3 Menus & Pages

The description of each screen follows below. Each screen given a page number, starting with Page 0 which is the warm-up page. There is text picture of the page itself, and below this is the label “Go to” with 3 boxes showing the actions of the 3 buttons.

Warm – Up Page

| Page 0 | Tandem PRO/HEXA analyser<br>Magellan Instruments<br>version 1.12<br>*** Initialising *** |
|---|---|
| Go to | | | |

This is shown while sensors are warming up and doing internal tests. This should not last longer than 2 minutes.

Main Page

| Page 1 | O2 XX.XX% LINE1<br>CO2 YY.YY%<br>Last Cal 03 hours/day A<br>Err ???? 03 Lines |
|---|---|
| Go to | | Page 2 | |

This shows the last values measured for both CO2 and O2.
If a Multiplex unit is used, the Line/Fermenter for those values is also shown. NOTE: Line 1 means the values are the gas concentration measurements for line 1 recently sampled, and not that line 1 is currently being sampled – in fact it will be line 2 that has gas flowing.
The last time a calibration was performed is shown, and A or M shows if it was an automatic or a manual calibration.
If there is an error, it is shown here (e.g. autocalibration was not carried out)
The number of active lines/fermenters in a Multiplex unit is shown on the last line.
Pressing the middle button takes you to the next Menu (page 2).

Calibration Display Menu

| Page 2 | Calibration Menu<br>Auto Cal Off/ ?? Hours/days<br>Last Cal 03 hours/days M/A<br>Enter Next > |
|---|---|
| Go to | Page 3 | Page 15 | Page 2.1 |

| Page 2.1 | Calibration Menu<br>cal O2 ±xxxx ±xxxx<br>val CO2 ±yyyy ±yyyy<br>Enter Next > |
|---|---|
| Go to | Page 3 | Page 15 | Page 2.2 |

| Page 2.2 | Calibration Menu<br>Auto Cal Off/ ?? Hours/days<br>Next ?? hours/days<br>Enter Next < |
|---|---|
| Go to | Page 3 | Page 15 | Page 2 |

To move between the three pages of the Calibration Menu, you use the right button. To enter the calibration sub menu (to start a calibration for example), you choose the left button “Enter” (go to page 3), or to pass to the next menu down (page 15), you press the middle button “Next”.

Page 2 shows whether automatic calibration is on or off, when the last calibration was carried out, and whether that calibration was automatically or manually performed.

Page 2.1 shows what the calibration values were. Over time, these numbers will change which reflects the health of the sensors. Generally, the unit will be serviced before any significant change occurs.

Page 2.2 shows when the next automatic calibration will be carried out.

Calibration Gas Values

Page 3

| Using Cal Gases |
|---|
| O2 10.17% & 17.62% |
| CO2 01.03% & 03.00% |
| Change Next Esc |

Go to

| Page 4 | Page 8 | Page 1 |
|---|---|---|

Upon entering the calibration sub-menu, you either press the middle button (Next, Page 8) to start or modify a calibration or press the left button (Change, page 4) to edit the values of the two calibration gases you will use. You will only change the values when you change gas bottles or supplies that have different calibration certificates. This means you do not need to enter the values every time you perform a calibration, and the automatic calibration will work correctly.
Pressing the right button (Esc, page1) exits without changes and takes you back to the Main Page.

Change Calibration Gas Values

Page 4

| Enter values Gas 1 |
|---|
| O2 xx.xx% |
| CO2 yy.yy% |
| Inc OK > |

Go to

| Add | Page 5 | Mov1 |
|---|---|---|

Page 5

| Confirm Selection |
|---|
| Gas1 O2 10.17% |
| Gas1 CO2 01.03% |
| Change OK Esc |

Go to

| Page 4 | Page 6 | Page 1 |
|---|---|---|

Page 6

| Enter values Gas 2 |
|---|
| O2 xx.xx% |
| CO2 yy.yy% |
| Inc OK > |

Go to

| Add | Page 7 | Mov1 |
|---|---|---|

Page 7

| Confirm Selection |
|---|
| Gas2 O2 17.62% |
| Gas2 CO2 03.00% |
| Change OK Esc |

Go to

| Page 6 | Page 3 | Page 1 |
|---|---|---|

To change the first gas concentration, you use the right button to move the cursor to the appropriate figure, and then use the left button to increase the number.
Pressing OK in the middle progresses you to the next stage.

Page 5 confirms the two values of O2 and CO2 that you have just entered. If you have made a mistake, and wish to modify the values, the left button (Change) takes you to page 4. If you wish to escape to the main page without making any changes, press the right button (Esc).
Pressing OK in the middle enters the new values into the system.

The same process is repeated for the second gas on the next two pages.

Autocalibration

Page 8

| Auto Cal Time |
|---|
| Currently Off/every |
| ?? Hours/days |
| Change Next > |

Go to

| Page 9 | Page 10 | Page 8.1 |
|---|---|---|

Page 8.1

| Auto Cal Time |
|---|
| Next Auto Cal |
| YY-MM-DD HH:MM |
| Change Next < |

Go to

| Page 9 | Page 10 | Page 8 |
|---|---|---|

The autocalibration function is shown to be off, or to be running at a specific time interval. Pushing the right button swaps to a second page showing the precise time when the next autocalibration is due.

Pressing the left button (Change) allows a change to be made to the autocalibration function. Pressing the middle button moves to the next calibration menu option (page 10) which is for manual calibrations.

Page 9

| Run AutoCal every | |
|---|---|
| ?? Hours/days | 00 = Off |
| Inc | OK h/d |

| Go to | Page 9 | Page 8 | Page 9 |
|---|---|---|---|

You change the time interval between autocalibrations by choosing the an interval based either on days or hours (right button) and the number (left button). If you choose 0 then the autocalibration function is switched off.

When an automatic calibration is due, the following screens will appear automatically:

Page 39

| Auto Calibration |
|---|
| will start in |
| 9 minutes |
| Skip OK |

| Go to | Page 40 | Page 1 | |
|---|---|---|---|

An information screen appears 9 minutes before the routine will start, showing a countdown until the automatic calibration is due to start.
Pressing OK (middle button) returns the main front screen, but after one minute the autocalibration information page will return.
You can choose to skip the autocalibration completely by pressing the left button.

Page 40

| Auto Calibration |
|---|
| Skipped |
| Next run in ?? Hours/days |
| OK |

| Go to | | Page 1 | |
|---|---|---|---|

A confirmation appears showing when the next autocalibration is due.

Page 41

| Auto Calibration |
|---|
| Running |
| (Progress) |
| Skip |

| Go to | Page 40 | | |
|---|---|---|---|

Once the routine starts, the valves will open and close automatically to enable the two different calibration gases to be sampled and the zero and offset to be calculated.
"Test Gas 1" and "Test Gas 2" will be displayed when the relevant gas is being measured.

Page 42

| Auto Calibration |
|---|
| Finished |
| Next run in ?? Hours/days |
| OK |

| Go to | | Page 1 | |
|---|---|---|---|

If successful, this page will appear and will last for 1 minute or until OK (middle button) is pressed.

Page 42.1 or

| Auto Calibration |
|---|
| Failed |
| Auto Calibration OFF |
| OK |

| Go to | | Page 1 | |
|---|---|---|---|

If there is a problem for any reason and the calibration fails, then this page will be displayed. You will need to acknowledge this page by pressing OK (middle button).
The most likely problem is the gases not reaching the sensors for reasons such as badly connected tubing and empty gas bottles.
It may also indicate that the sensors are in need of repair or replacement.

## Manual Calibration

| | |
|---|---|
| Page 10 | Perform Manual Cal<br>with the two test<br>gases<br>Run Next Esc |
| Go to | Page 11 \| Page 3 \| Page 1 |

To perform a manual calibration, you press the left button, “Run”. Note that you must have previously entered the values for each calibration gas in pages 4-7 above.

| | |
|---|---|
| Page 11 | Test Gas 1 ON<br>OK when settled<br>xxxx yyyy<br>Cancel OK Esc |
| Go to | Page 10 \| Page 12 \| Page 1 |

The first test or calibration gas line is automatically opened by the Tandem. Please ensure you have correctly connected the calibration gases to system.
When the reading on the screen has settled, press the middle button, “OK”. Otherwise you may cancel back to the manual calibration page, or escape to the main page.

| | |
|---|---|
| Page 12 | Gas 1 values saved<br><br><br>OK Esc |
| Go to | \| Page 13 \| Page 1 |

A confirmation page then appears.
Pressing the right button, “escape”, will re-instate the original calibration without any changes.

| | |
|---|---|
| Page 13 | Test Gas 2 ON<br>OK when settled<br>xxxx yyyy<br>Cancel OK Esc |
| Go to | Page 10 \| Page 14 \| Page 1 |

The second test / calibration gas then is let in automatically.
Press the middle button “OK” when the two values have settled.
Pressing either cancel or escape at this point will discard any changes, and return the system to the previous calibration status.

| | |
|---|---|
| Page 14 | Confirm Calibration<br>new O2 ±xxxx ±xxxx<br>val CO2 ±yyyy ±yyyy<br>Cancel OK Esc |
| Go to | Page 10 \| Page 2 \| Page 1 |

A final chance to reject or accept the new calibration result. The calibration errors are shown, in case there is a problem with the system.

## Setup and Configuration Options

| | | | | | |
|---|---|---|---|---|---|
| Page 15 | Set-up<br>Pump Status On/Off<br>Comms Option ??<br>Enter Next > | Page 15.1 | Set-up<br>Lines Used ??<br>Line timings ??? secs/Auto<br>Enter Next > | Page 15.2 | Set-up<br>Return to factory<br>settings<br>Enter Next < |
| Go to | Page 16 \| Page 20 \| Page 15.1 | Go to | Page 16 \| Page 20 \| Page 15.2 | Go to | Page 16 \| Page 20 \| Page 15 |

The Set-up pages show some advanced settings that you will probably not wish to change too often. You should use the right button, “>” or “<”, to scroll between them. The pages show whether the internal pump is on or off, which communications option is selected, what is the selected status of the multiplexer valve system, and that you may return to factory settings by entering the sub-menu.

For a multiplexed unit, you may wish to reduce the number of possible lines if you are only running one or two fermenters, and you wish to sample more regularly, e.g. once every minute from two lines and ignore lines 3-6, rather than once every 6 minutes for every line.

If you have a problem that you can't fix, or have modified settings unknowingly, you can enter the setup menu to return to factory settings. You should then perform a calibration before re-using the unit.

| | | | |
|---|---|---|---|
| Page 16 | Turn Pump<br><br>On/Off Next Esc | | |
| Go to | Page 16 | Page 17 | Page 1 |

You can turn the internal pump off or on from this page. You may wish to turn off the internal pump if you are using a small fermenter where the total gas flow is less than the pump uses. Our recommendation is to do this when your total gas flow is less than 1L/min. In this case, all the gas coming from the fermenter will pass through the Tandem.

| | | | |
|---|---|---|---|
| Page 17 | Change Comms status<br>Option 1<br><br>Change Next Esc | | |
| Go to | Page 17 | Page 18 | Page 1 |

For a multiplex system, you can choose between option 1 and option 2 on the Comms status. Option 1 means the output will contain data for every line, whereas option 2 will mean the output only contains the last line measured.

| | | | |
|---|---|---|---|
| Page 18 | Lines used ??<br><br>Inc Next Esc | | |
| Go to | Page 18 | Page 19 | Page 1 |

On a multiplex system, you can select how many lines will be active. The unit will then measure only up until the number you enter, ignoring the higher lines.

| | | | |
|---|---|---|---|
| Page 19 | Change line timings<br>xxx seconds per line<br><br>Inc Next Esc | | |
| Go to | Page 19 | Page 33 | Page 1 |

We recommend using at least 60 seconds for each line to ensure there is enough time for the gas from the fermenter to reach the sensors, and for them to measure the concentrations accurately.
If your fermenters are far away, or very close, you may wish to increase or decrease the timings to ensure proper measurements are taken.

| | | | |
|---|---|---|---|
| Page 33 | Return to factory settings<br><br>Enter Next Esc | | |
| Go to | Page 34 | Page 16 | Page 1 |

From this page you may select Enter to return the unit to it's factory settings. This will mean the memory loss of your calibration gases and calibration values.

Some intermittent faults, such as display screen errors caused by mains power voltage spikes, can be rectified by a return to factory settings.

| | | | |
|---|---|---|---|
| Page 34 | Factory settings<br>will now be restored<br><br>Yes No Esc | | |
| Go to | Page 34a | Page 33 | Page 1 |

| | | | |
|---|---|---|---|
| Page 34a | Factory settings<br>have been restored<br><br>Next Esc | | |
| Go to | | Page 16 | Page 1 |

You must confirm that you do wish to return to factory settings but selecting Yes, left button. Doing so gives you a confirmation screen. You may exit to the set up sub-menu, Next on the middle button, or back to the main display by choosing Esc, right button.

If you do not wish to restore factory settings, you may select No, middle button, to return to the previous screen, or Esc, right button to return to the main display page.

Service Menu

Page 20

| Service Menu | | |
|---|---|---|
| Date | YY-MM-DD | |
| Time | HH-MM-SS | |
| Enter | Next | > |

Go to

| Page 21 | Page 1 | Page 20.1 |
|---|---|---|

Page 20.1

| Service Menu | | |
|---|---|---|
| Next service due yy-mm-dd | | |
| Last service yy-mm-dd | | |
| Enter | Next | > |

Go to

| Page 21 | Page 1 | Page 20.2 |
|---|---|---|

Page 20.2

| Service Menu | | |
|---|---|---|
| Serial Number ???? | | |
| Enter | Next | > |

Go to

| Page 21 | Page 1 | Page 20.3 |
|---|---|---|

Page 20.3

| Service Menu | | |
|---|---|---|
| O2 = 30% | CO2 = 10% | |
| Serial Number ???? | | |
| Enter | Next | < |

Go to

| Page 21 | Page 1 | Page 20 |
|---|---|---|

The service menu has 4 pages you can scroll sequentially between using the right button, “>”.

They show the current date and time, the last and next due service dates, the serial number and the sensor ranges.

If you wish to change the time, you can do so by pressing the left button on any of the screens.

You cannot change the date nor the sensor ranges of the unit. These are set at the factory.

Page 21

| Time | | |
|---|---|---|
| hours mins secs | | |
| hh - mm - ss | | |
| hours | Next | mins |

Go to

| | Page 20 | |
|---|---|---|

You can adjust hours and minutes incrementally by using the left and right buttons. The middle button saves the new time, and return to the service menu.

# 6. Technical Details

## 6.1 Oxygen Sensor

The sensor is an advanced zero-maintenance, high-output temperature-compensated oxygen sensor. It is specific to oxygen measurement and is virtually unaffected by other gases in the atmosphere.

### 6.1.1 Principle

The principle is based on electrochemical galvanic action and produces electrical current proportional to the absorption of oxygen through the Teflon membrane on the sensor. The absorption rate through the Teflon membrane is in turn proportional to the partial pressure of oxygen in the gas to be analysed. As neither the Teflon membrane nor the partial pressure of oxygen is affected by most other gases, the sensor output is virtually immune to cross interference.

### 6.1.2 Construction

The electrodes and electrolyte are hermetically sealed in a polyethylene sensor body to prevent leakage and provide resistance to a wide range of chemicals in solid liquid or gaseous form. The sensor body is further retained in a tough precision-machined housing. The sensor is guaranteed for one year and will normally need replacing every 12-18 months.

### 6.1.3 Temperature Compensation

Many types of oxygen sensors are affected by temperature, this sensor has a compensation circuit built in and as it monitors it automatically regulates its output thus eliminating temperature effects. This temperature compensation circuit is computer-profiled for each sensor and provides a consistent and accurate performance.

### 6.1.4 Operational Properties

This sensor is equipped with a hydrophobic membrane to protect the Teflon membrane from physical damage and helps avoid the effects of water contamination on the sensor face in environments of high humidity.

## 6.2 Carbon Dioxide Sensor

The sensor incorporates an advanced infrared carbon dioxide measurement and is virtually unaffected by other gases in the atmosphere. It is a solid state sensor and uses the highest quality infrared source and detector components. It has a narrow band pass filter with an extremely close tolerance, which ensures that the sensor is very specific to carbon dioxide.

### 6.2.1 Temperature Compensation

The temperature compensation is achieved using a unique smart detector technology and is further enhanced with an active temperature probe mounted in the infrared bench. This eliminates almost all measurable temperature effects in the operating range.

### 6.2.2 Drift Compensation

Drift caused by source ageing is compensated in the sensor by monitoring the infrared output of the source and automatically applying the calculated age correction factor to the detector signal.

### 6.2.3 Optical Protection

The detector, filter and source optics are protected from contamination by a gas-permeable Teflon membrane to eliminate external sources of sensor drift.

## 6.3 Sensor Specifications

| | CO2 | O2 |
|---|---|---|
| Measurement Principle | Infra Red Absorption | Electrochemical galvanic |
| Ranges (partial pressure) | 0-5%, 0-10%, 0-20% | 0-30% 0-50%, 0-100% |
| Resolution | 0.01% | |
| Accuracy | 1% of range | |
| Temperature Effects | 0.1% of range / °C | 0.2% of reading / °C |
| Drift | 2% of range / year | 5% of range / year |
| Operating Temperature | 0 - 50°C | |
| Humidity | 0-99 %RH non condensing | |
| T90 Response Time | 50 secs | 10 secs |
| Gas flow rate | 0.05 - 1.0 L/min | |
| Guarantee | 1 year | |
| Calibration | Standard 2 point non-zero calibration in any instrumentation or software | |

To give an example of accuracy of a reading, if a Tandem TGA-30-10 is calibrated in a room at 20 deg C and subsequently the room heats to 25 deg C, the following errors apply to a 7% concentration of gas:
CO2, 10% range: (0.01 x 10) + 5 x (0.001 x 10) = 0.1 + 0.05 = 0.15% absolute error possible
O2, 30% range: (0.01 x 30) + 5 x (0.002 x 7) = 0.3 + 0.070 = 0.37% absolute error possible

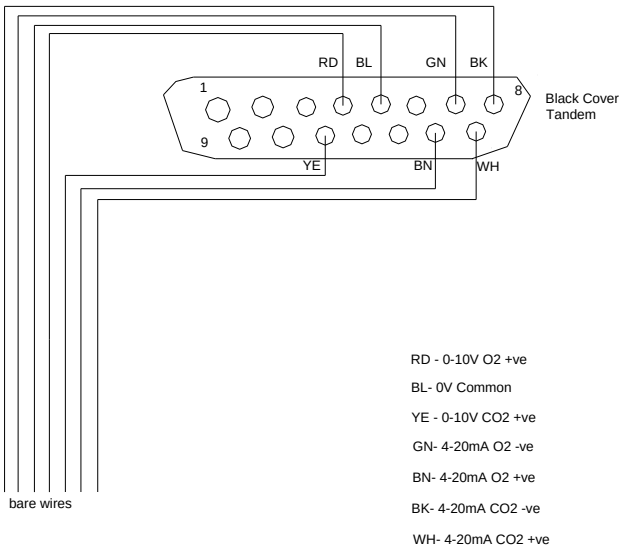
This error is the maximum we specify for quality purposes and you should expect much better performance in practice. If the unit is calibrated at the same temperature as it will be used, then one part of the error is removed. If you then ensure the Tandem is serviced at least once every 2 years, the average error you should expect is about 0.5% of the full range for a 10-30% range of either sensor.

## 6.4 Signal Cable Descriptions & Drawings

### 6.4.1 Bare wires cable

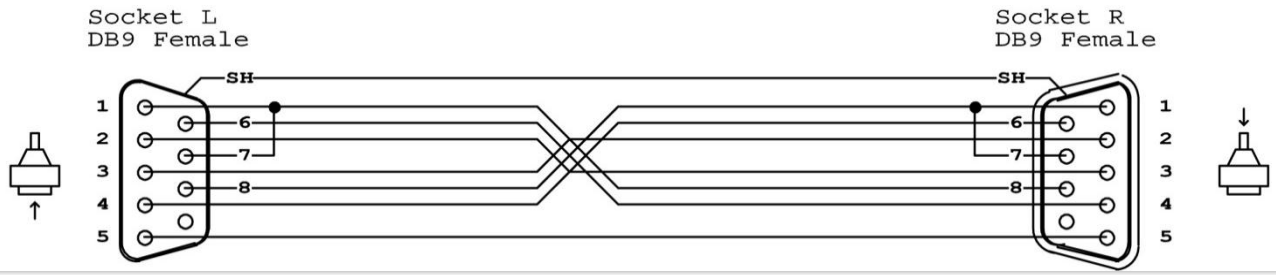
The following are the output connections on the 15 way D connector on the rear of the Tandem, and the associated bare wires cable:

| Pin No. | Wire Colour | Output | Parameter |
|---|---|---|---|
| 4 | Red | 0 - 10V | $O_2$ + signal |
| 5 | Blue | 0 - 10V | Common Zero (V) |
| 7 | Green | 4 - 20mA | $O_2$ - signal |
| 8 | Black | 4 - 20mA | $CO_2$ - signal |
| 11 | Yellow | 0 - 10V | $CO_2$ + signal |
| 14 | Brown | 4 - 20mA | $O_2$ + signal |
| 15 | White | 4 - 20mA | $CO_2$ + signal |

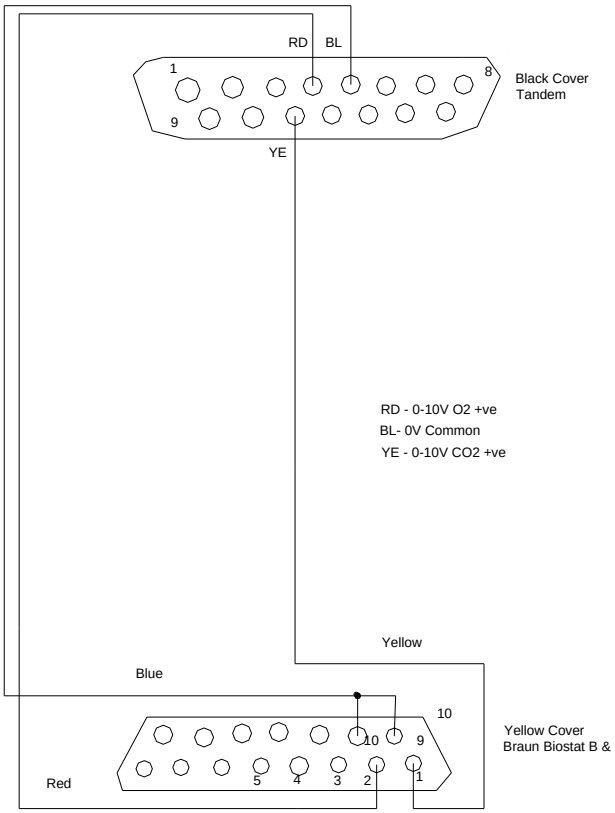



### 6.4.2 RS232

This is the RS232 cable configuration (DB9 Null Modem, Cross Over):



### 6.4.3 Braun BioStat Cable (B/C/+)

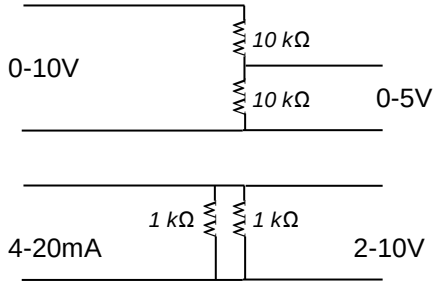



### 6.4.4 Multiplex Voltage and milliAmp signal cable

| Wire | Colour | Gas | Line Signal | Sign |
|---|---|---|---|---|
| 1 | Green | O2 | 1 or 7 | - |
| 2 | Red | O2 | 1 or 7 | + |
| 3 | Blue | CO2 | 1 or 7 | - |
| 4 | Yellow | CO2 | 1 or 7 | + |
| 5 | Green | O2 | 2 or 8 | - |
| 6 | Red | O2 | 2 or 8 | + |
| 7 | Blue | CO2 | 2 or 8 | - |
| 8 | Yellow | CO2 | 2 or 8 | + |
| 9 | Green | O2 | 3 or 9 | - |
| 10 | Red | O2 | 3 or 9 | + |
| 11 | Blue | CO2 | 3 or 9 | - |
| 12 | Yellow | CO2 | 3 or 9 | + |
| 13 | Green | O2 | 4 or 10 | - |
| 14 | Red | O2 | 4 or 10 | + |
| 15 | Blue | CO2 | 4 or 10 | - |
| 16 | Yellow | CO2 | 4 or 10 | + |
| 17 | Green | O2 | 5 or 11 | - |
| 18 | Red | O2 | 5 or 11 | + |
| 19 | Blue | CO2 | 5 or 11 | - |
| 20 | Yellow | CO2 | 5 or 11 | + |
| 21 | Green | O2 | 6 or 12 | - |
| 22 | Red | O2 | 6 or 12 | + |
| 23 | Blue | CO2 | 6 or 12 | - |
| 24 | Yellow | CO2 | 6 or 12 | + |

### 6.4.5 Converting milliamps and voltages

If your fermenter system can only accept 0-5V or -5V to +5V, then you need to convert the 0-10V signal into a 0-5V. If you need to have a cable length of more than 5m/15ft, it is advisable to use the mA signal not the voltage. Therefore you may also wish to convert the mA to V just prior to entering the fermenter controller. Here are two diagrams showing how to achieve this using common resistors across the voltage wires:







### 6.5 RS232 Protocol and Connection Instructions

RS232 communications details: FULL DUPLEX, 8 DATA BITS, PARITY NONE, 1 STOP BIT, 2400 BPS

The protocol used is as follows:

[Serial No.]; [date]; [time]; [channel]-X2 xx.xx%; [channel]-CO2 yy.yy%;

This is an output from the Multiplexer system:

0001; 27-03-06; 11:20:00; 01-X2 19.78%; 01-CO2 00.19%; 02-X2 19.75%; 02-CO2 00.19%; 03-X2 19.78%; 03-CO2 00.19%; etc.

For a PRO system, the channel number will always be 01 since there is only one channel.

For a Multiplexed system, there are two options available in the menu system to change the output:
Option 1 will send out every channel at the same time, even if only one or two are being updated.
Option 2 will send out only the last line which was measured.

There is no two way communication currently possible to instruct the Tandem to swap channels or perform a calibration.

### 6.6 RS232 Software

We do not sell software with the Tandem range. Normally the best results come when the analysers are plugged into your fermenter control software to allow closed loop feed back control.

However, if you wish to have separate logging software, we recommend windmill.co.uk who provide free RS232 software. This package is quite basic but functional. If you need more a more sophisticated solution, then we recommend National Instruments LabView. These companies also provide ADDA boards to plug into computers to allow data capture when you wish to use the voltage or milliamp outputs.

We do NOT support these packages – please contact the vendors directly.

### 6.7 Electrical Details

All Tandem units have a 250mAT (T means Anti surge) fuse fitted. The power rating for each is as follows:

TGA 5 watts
PRO & Multiplex: 24 watts (19 watts without pump on)

### 6.8 Physical Details

| Model | Weight, kg | Dimensions, mm (w d h) | Shipping Weight, kg | Shipping Dimensions, mm (w d h) |
|---|---|---|---|---|
| TGA | 5 | 250 x 260 x 170 | 6.5 | 470 x 330 x 320 |
| PRO | 6.5 | 250 x 260 x 170 | 8 | 470 x 330 x 320 |
| HEXA | 10.5 | 320 x 260 x 410 | 13 | 560 x 430 x 330 |
| OCTO | 11.5 | 320 x 260 x 410 | 14 | 560 x 430 x 330 |
| DODI | 13.5 | 320 x 260 x 410 | 16 | 560 x 430 x 330 |

### 6.9 Materials used

The Tandem is designed to sit outside the sterile barrier in a standard laboratory or factory environment, typically for fermentations involving E Coli, yeasts, fungi etc. High concentrations of alkali or acid in the gas stream should be avoided (e.g. NH3 or SO2) since they could both poison the sensors and degrade some parts.

The materials used inside the Tandem and those which are in contact with the process air include (not an exhaustive list): Brass, stainless steel, polyacetal, polymide 6, nickel plated brass, PVC, norprene A-60-F, Acrylic, Buna-N, Teflon.

### 6.10 Summary of Features & Model Comparison

| Model name | TGA | PRO | Multiplex |
|---|---|---|---|
| No. of lines | 1 | 1 | 6, 8 or 12 |
| Sampling interval | Continuous | Continuous | User definable, from 30 seconds |
| Local display | No | Yes | Yes |
| Calibration, with two known gases | Manual on fermenter controller | Manual & Automatic on local display | Manual & Automatic on local display |
| Gas flow rate | 25-1000 ml / min | | |
| Internal gas pump | No | Yes | Yes |
| Output | Dual 0-10V and 4-20mA | Dual 0-10V and 4-20mA plus RS232 | Either 0-10V **or** 4-20mA plus RS232 |

# 7. Maintenance and Guarantee

The Tandem is guaranteed for one year. During this time, we operate a “new for old” policy if the sensor experiences problems. This guarantee does not cover operator or installation errors, for example power surges or water or media invasion. After the guarantee period, you may service your Tandem when you choose. Generally, we recommend once a year.

The oxygen sensor is a consumable, and will last 18-24 months on average. Therefore, the maximum interval for servicing is 2 years if you wish to maintain good results.

**email - sales@magellaninstruments.com**
**Please quote the serial number in all correspondence**