

**Compendium
of
TRD Gas Control Electronics Functionality Test**

May 10th, 2006

**A.Bartoloni¹, C.Bosio¹, B.Borgia^{1,2}, H.B.Broker³, J.Burger³, F.Bucci^{1,2},
S.Gentile^{1,2}, M.Kamenetska³, A.Lebedev³, G.Rybka³, M.Sapinski¹,
F.R.Spada^{1,2}, A.Werner³**

Collected by B.Borgia

¹ INFN Sezione di Roma

² Università di Roma “La Sapienza”

³ LNS, Massachusetts Institute of Technology

1. Introduction

This document collects the main results of a long test campaign on the *control electronics* for the TRD gas circuit, started on December 2003. We performed various tests on gas circuit components, some of them on preliminary versions. In August 2004 the Rome and MIT groups performed a thorough test. Subsequently the goal was focused mainly on procedures to operate the gas circuit itself. Obviously at the same time these tests represent a further check of the *control electronics* functionality.

We planned some of the tests with detailed procedures reported here. During the full test of August 2004, a meeting was held to evaluate the status of the test itself.

All these documents are collected here.

The following paragraphs give some details and explanations on the collected documents.

The reference section contains the list of attached documents.

References [1] and [2] concern the test planning. References [3], [4] and [5] report tests on each gas circuit modules. Reference [6] contains the minutes of the evaluation meeting held during the August 04 test. Reference [7] reports the full test of August 04 and references [8] [9] and [10] report final tests performed in Rome on specific items of the gas circuit.

2. Gas Circuit and Control Electronics layouts

Some of the names of gas circuit components or of *control electronics* modules changed. The following figure 1 show the current version of the gas circuit and figure 2 shows the current block diagram of the *control electronics*.

When necessary, the following paragraphs specify the current names.

3. UGFV/UGPS test

Reference [3] describes the basic test on the manifolds and differential pressure sensor performed by the UGFV command module, previously called UGM, and by the preamplifier card now called UGPS.

Aside from missing manifold channel 6 and valve A4 not functioning, all other elements were functioning as expected.

Command pulse to open/close the flipper valve was tested from 10 ms to 120 ms. The minimum duration necessary to operate the valves is 10 ms.

The output from the differential pressure sensors has the sensitivity of $\approx 1\text{mV}/1\text{mbar}$.

Normal operation will result in $\Delta p = 50\text{ mbar}$ equivalent to $\approx 50\text{ mV}$.

A loss of pressure in one TRD segment will give a maximum $\Delta p \approx 1.2\text{ bar}$, equivalent to 1.2 V.

Reference [8] shows that manifolds and pressures were operated/read correctly for all working elements.

4. UGBS test

Reference [4] shows that the *control electronics* reads correctly the pressure sensors GP-50. Electronic readings are consistent with visual reading on mechanical gauge or Omega sensors within $\approx 1\%$. Also all working Marotta valves were operated correctly.

Timing was also tested and valves could be opened safely with pulse duration from 8 ms up to the maximum time of 65.6 s.

Reference [8] shows that all operations on Box S could be performed. The overlapping opening of valves V6a + V18a, or V6b + V18b, or any other pair was tested and verified successfully.

5. UGBC test

References [5], [6] and [7] report tests validating the operations of all valves. Instead excitation voltage of GP50 pressure sensors needed to be modified and also the 12V pumps power supply must not relay on drawn current. Functionality to turn on/off the spirometer and the MCA should be added.

Reference [8] shows that MCA is fully consistently read. Spirometer is also read. Reference [9] reports a complete test of the UGBC monitor tubes control through MCA reading and operation of the UHVG module. The monitor tubes were equipped with ^{55}Fe source and from them we obtained pulse height spectra. Photo peak and escape peak are fitted with two Gaussian curves plus an exponential to simulate the background and the positions of the two peaks roughly agree, with the escape peak value being half of the photo peak.

6. Dallas sensor calibration

Reference [10] reports the calibration of Dallas sensors read with the UGSCM and the reference temperature sensors independently read with Labview on a different PC. This test demonstrates that operations through Dallas channel read-out give consistent results.

7. Conclusions

Subsequently after specific element testing, an intensive campaign of gas mixing procedures was performed in Rome lead by Ulrich Becker with the participation of Alessandro Bartoloni, Carlo Bosio, Francesca Bucci, Simonetta Gentile, Piero Rapagnani and Francesca Spada. This work, outside the scope of testing the *control electronics* functionality, will be reported in the Francesca Bucci's Physics doctor degree thesis. Following this campaign, the Electronics Lab in Rome executed a complete rewiring of all Gas Circuit components connections to UG modules to correct the noise previously found on pressure sensor readings. The rms readings of GP50 before and after the rewiring were:

| GP50 | rms/mean before | rms/mean after |
|------|---------------------|---------------------|
| P1a | $3.6 \cdot 10^{-3}$ | $2.3 \cdot 10^{-3}$ |
| P1b | $1.8 \cdot 10^{-2}$ | $2.8 \cdot 10^{-3}$ |

8. Acknowledgements

A special thanks is due to our MIT and INFN Rome technicians that were skillfully executing all our urgent and often unplanned requests.

References

- [1]. A.Werner: Box-C Electronics Test Plan; May 13, 2004
- [2]. F.Spada, A.Werner: Preparation for Integrated TRD Gas System Electronics Test; August 4, 2004
- [3]. A.Bartoloni, C.Bosio, J.Burger, S.Gentile: AMS-02 TRD Gas System Manifold Electronics Test; CERN, December 10-11, 2003
- [4]. A.Bartoloni, C.Bosio, J.Burger, S.Gentile, F.Spada: AMS-02 TRD UGBS Electronics Test on Engineering Box S; CERN, March 15-19, 2004
- [5]. A.Bartoloni, C.Bosio, J.Burger, S.Gentile, F.Spada, A.Werner: AMS-02 TRD UGBC Electronics Test on Engineering Box-C; CERN, June 7, 2004
- [6]. Minutes of TRD Gas Electronics Meeting; CERN, August 11, 2004
- [7]. A.Bartoloni, B.Borgia, H.B.Broker, J.Burger, M.Kamenetska, A.Lebedev, G.Rybka, F.Spada, A.Werner: August 2004 AMS-02 TRD Electronics Test; CERN, August 20, 2004
- [8]. A.Bartoloni, B.Borgia, F.Bucci, F.R.Spada: Integrated test of the TRD Gas System Electronics; CERN and Rome, March 6, 2006
- [9]. F.Bucci, F.R.Spada: Read-out of the Multichannel Analyzer and test of the monitor tubes; Rome, February 10, 2006
- [10]. M.Sapinski: Calibration of Dallas Sensors, Rome, April 2006.

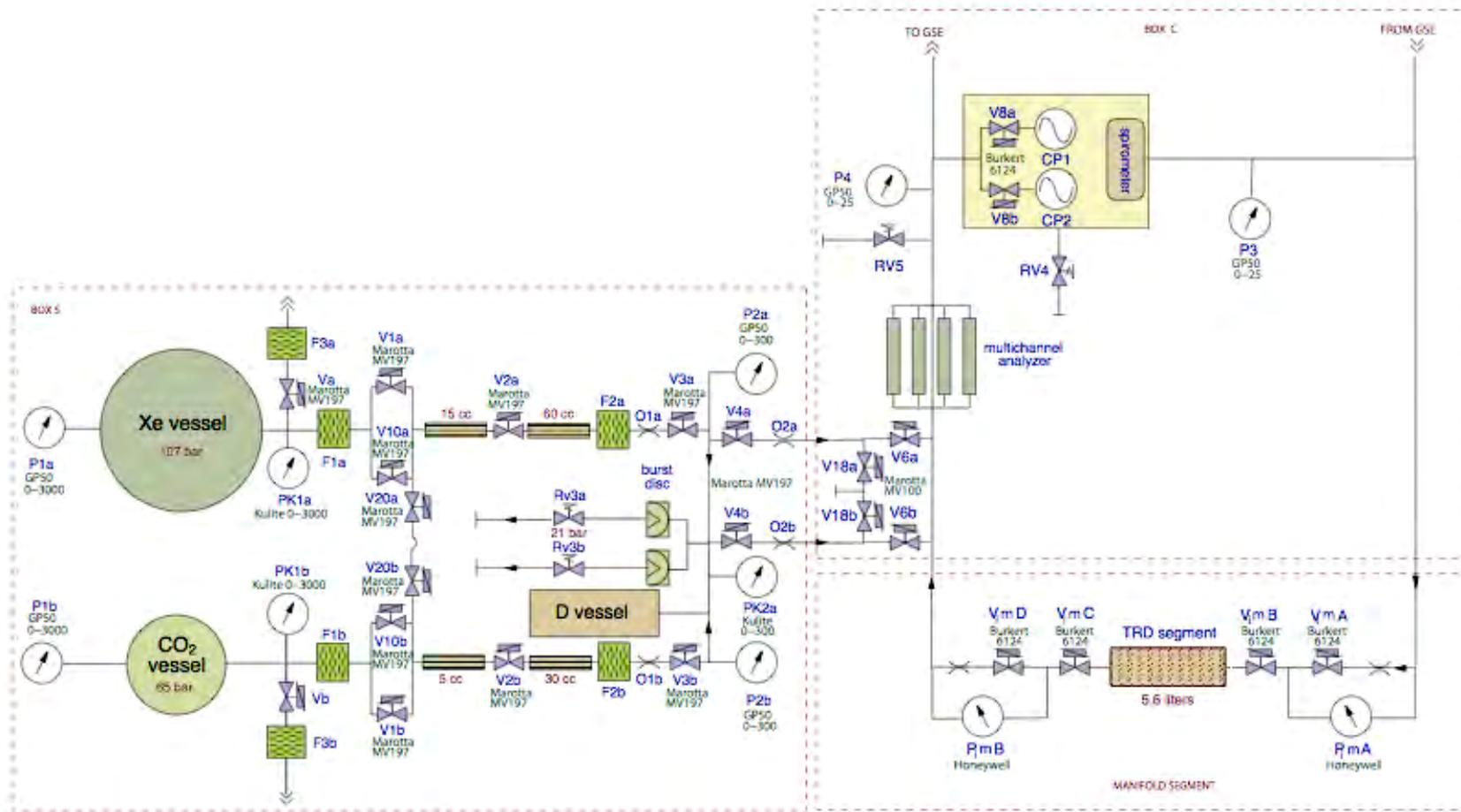


Figure 1: Gas Circuit

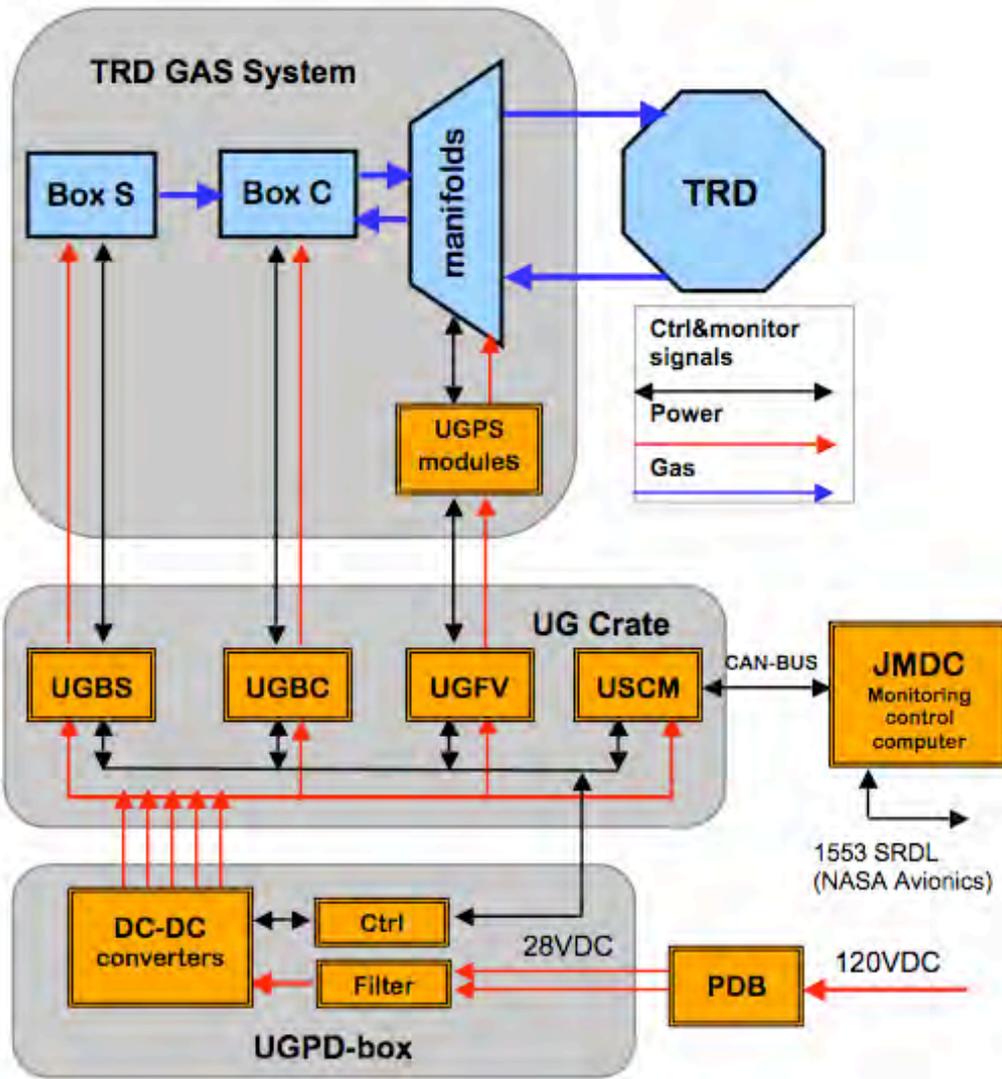


Figure 2: Control Electronics block diagram

Reference [1]

Box-C Electronics Test Plan

Andrew Werner

awerner@mit.edu

Ph: +1 617 253 4436

May 13, 2004

1 Purpose

This document is a plan proposal for the electronics tests to be carried out on Box-C at CERN the week of 17 May 2004. Comments are welcomed from all.

2 Test Setup

The test will take place in two main stages. The first stage is chiefly meant to demonstrate the proper control of the equipment inside the Box-C canister, with the corollary that the ability of the system to circulate gas will be validated for future procedures. The second stage is meant to demonstrate a successful fill/vent of the system in closed circulation,

The two stages have slightly different setups, which are given in Figures 1 and 2. Please note that unlike the flight version of Box-C, only P4 will be a GP:50 0-25 psi pressure sensor. The other will be an Omega (or similar) sensor that gives a visual display of the pressure. This is due to a need to save components that have gone through the MIT acceptance procedure for the flight model.

3 Test Procedures

3.1 Open Circulation Tests

This test is performed with the system configured as in Fig. 1. The test should begin with all valves closed by some reliable means and both circulation pumps off. In addition, valves **V6a**, **V6b**, **V18a**, and **V18b** should all be closed throughout the entire portion of the test.

1. Read **P4** and **P5**.
2. Set **CP1** to speed “low”.

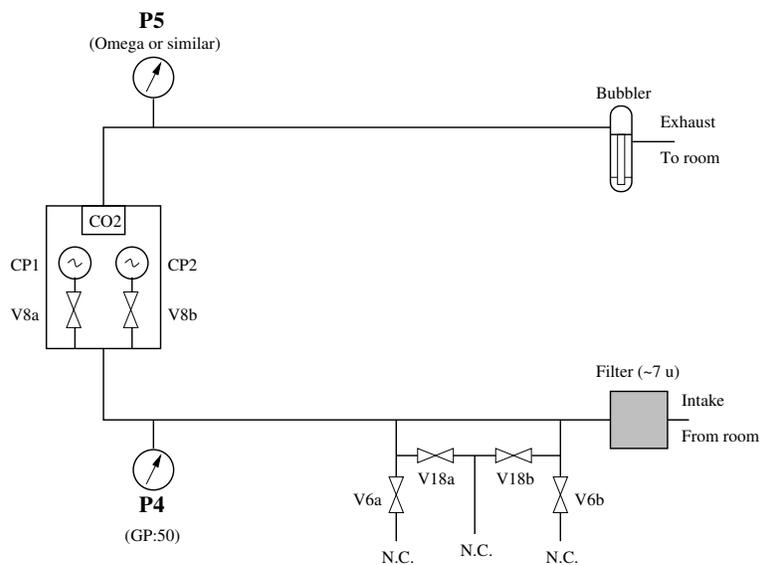


Figure 1: Setup for system tests in open circulation, with the room air serving as gas supply.

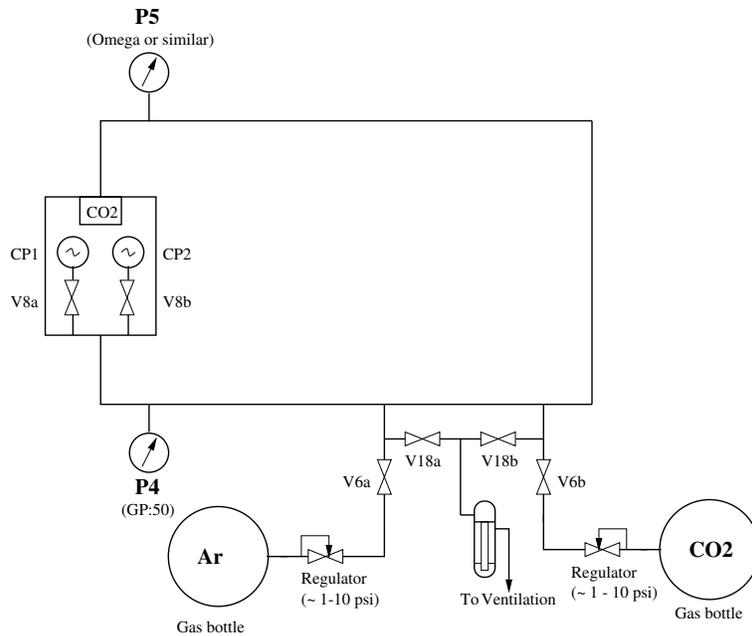


Figure 2: Setup for system tests in closed circulation.

3. Read **P4** and **P5**. Observe bubbler for evidence of gas flow.
4. Open **V8a**.
5. Wait 5 seconds.
6. Read **P4** and **P5**.
7. Close **V8a**.
8. Wait 5 seconds.
9. Read **P4** and **P5**.
10. Open **V8a**.
11. Set **CP1** to speed “high”.
12. Wait 5 seconds.
13. Read **P4** and **P5**.
14. Turn pump **CP1** off.
15. Close **V8a**.
16. Repeat previous steps with branch (b).

3.2 Closed Circulation Tests

This portion of the test is performed with the system configured as in Fig. 2. As before, the test begins with all valves closed and all pumps off.

1. Set regulators on both gas bottles to ~ 5 psi overpressure.
2. Open **V6a**.
3. Wait 5 seconds.
4. Read **P4** and **P5**. Observe pressure sensor **PT1**
5. Close **V6a**.
6. Open **V8a**.
7. Set **CP1** to speed “low”.
8. Wait 5 seconds.
9. Read **P4** and **P5**.
10. Turn pump **CP1** off.
11. Open **V18a**.

12. Wait 60 seconds.
13. Close **V18a**.
14. Verify return to atmospheric pressure.
15. Repeat preceding steps with branch (b).

3.3 Canister Electronics, Monitor Tubes

The Box-C canister contains four Dallas DS18S20 temperature sensors, an Amptek Pocket MCA (PMCA,) and a spirometer by ndd to be used for CO₂ measurements. The temperature sensors are organized in to two busses, each bus containing two sensors connected in parallel. The spirometer communicates via an RS-232 interface as described in [1]. The monitor tube readout board requires two TTL or 5V CMOS level signals to select which tube is read out.

3.3.1 Spirometer

While the operation of the spirometer can be verified in any gas mixture, the usage of separate Ar and CO₂ bottles as supplies allows for an observation of the change of ultrasonic transit time with gas mixture. This can be accomplished by periodically reading out the spirometer during sequential flushes of the closed Box-C system with argon and CO₂.

The system should be set up as in Fig. 2 for this test. All valves should be closed, and both pumps turned off.

1. Set the regulator on each gas bottle to approximately 5 psi overpressure.
2. Open **V8a**.
3. Set **CP1** to speed “low”.
4. Open **V6a** and **V18a**. (*Flush with argon.*)
5. Wait 180 seconds. During this time, read spirometer at intervals of approximately 10 seconds.
6. Close argon bottle.
7. Close **V6a** and **V18a**.
8. Open **V6b** and **V18b**. (*Flush with carbon dioxide.*)
9. Wait 180 seconds. During this time, read spirometer at intervals of approximately 10 seconds.
10. Close carbon dioxide bottle.
11. Close **V6b**.
12. Wait for the system to reach atmospheric pressure.
13. Close **V18b**.

3.3.2 Dallas Sensors

In addition to the Dallas sensors in the canister, MIT will bring two additional sensors wired identically to the busses inside the canister.

1. Read temperature from Dallas bus 1 in canister.
2. Read temperature from Dallas bus 2 in canister.
3. Read temperature from Dallas sensors outside canister.

3.3.3 Monitor Tube Readout Board

Monitor tubes will not be brought to this electronics test, so instead of a monitor tube readout board, MIT will bring a board with LEDs that display the channel selected by the control electronics. For this, the procedure consists of “selecting each channel” in sequence. Here, L denotes logical low and H logical high. The line status is written with the most significant bit first.

1. Set select lines to **LL**. Observe LED status.
2. Set select lines to **LH**. Observe LED status.
3. Set select lines to **HL**. Observe LED status.
4. Set select lines to **HH**. Observe LED status.

4 Materials

Table 4 contains a list of items required for the test setup, and the institutes responsible for bringing those items to the test. Items for which I have not received confirmation are indicated by *italics* in the **Supplier** column. In those cases, I have indicated my “best guess” for who will be supplying the items.

Please do not hesitate to contact me with any questions, corrections, or additions that regard this list or other matters.

5 Wiring Standards

As of this writing (11 May), an assembly consisting of the Box-C canister, the redundant pairs of valves V8 and V18, **one** GP:50 pressure sensor, a circuit board with two LEDs, Glenair connectors, and the attendant wiring has been sent to CERN.

There are a few unfinished items or potential problems with the setup that are described below. They should all be relatively quick to fix.

- The Dallas sensors are currently not wired to Glenair connectors. Pin assignments should be agreed upon; a total of six pins need to be assigned to assure full redundancy.

| Item | Supplier |
|--|-----------------|
| <i>Test Components</i> | |
| UGBC and USCM | Rome |
| Box-C canister | MIT |
| Box-C V6, V18, P4, P5 | MIT |
| MCA | MIT |
| Monitor tube dummy board | MIT |
| <i>Gas components</i> | |
| $\frac{1}{4}$ " inner diam. PVC tubing | CERN |
| $\frac{1}{8}$ ", $\frac{1}{4}$ " steel tube | CERN |
| $\frac{1}{8}$ " to $\frac{1}{4}$ " Swage union (2) | MIT |
| $\frac{1}{4}$ " Swage tee | MIT |
| Ar, CO ₂ gas bottles | CERN |
| Adjustable pressure regulators | CERN |
| $\sim 10\mu$ filter | CERN |
| <i>Electric/electronic components</i> | |
| Glenair connectors | MIT |
| Laboratory DC power supply | CERN |
| UG-crate or similar | Rome |
| Power for UG-crate | Rome |
| Computer interface to UGBC, USCM | Rome |
| Manual control box | MIT |
| Dallas "control" sensor | MIT |
| DB9 cable (if necessary) | MIT |

Table 1: Components to be brought to test, with suppliers.

- For the monitor tube readout boards, only two channel select lines are required, rather than the four indicated in an earlier pinout by B. Monreal, [2]. However, four lines will be required by the two two channel selects, since both inputs need to be differential. On the prototype sent to CERN, no connection has yet been made for the channel select return lines. If need be, they can be connected to UGBC ground for the purpose of this test.
- There is no explicit mention in the pinout about the polarity of the GP:50 excitation voltage.

6 Revision History

- 1.0 Original version, 27 April 2004.
- 1.1 Modified to incorporate open issues with pinouts and to reflect the lack of a pressure sensor P5. Suggested delay times were added to the test plan.

References

- [1] ndd ASIC Specifications A1 - A4. ndd Medizintechnik AG, Zurich (2003)
- [2] B. Monreal, *Box C conductors and connectors*. Available: <http://web.mit.edu/awerner/www/BoxCPinout.pdf>, 18 Dec 2001.

Preparation for Integrated TRD Gas System Electronic Test

Francesca Spada, Andrew Werner

August 4, 2004

1 Goals

This electronics test is meant to demonstrate the proper operation of the AMS-02 TRD Gas System electronics in full integrated configuration with the S, C, and M subsystems. The intent is to duplicate as closely as possible the configuration that will fly. We define two levels of test protocol for the purposes of clarifying exactly what will be required to specify the tender offer for the flight boards.

- **Level 1:** Confirm that UG-crate hardware can successfully control all S, C, and M components in a flight configuration. A Level 1 test would consist of making connection between all components under test (defined in the *Equipment* section), actuating all electromechanical components individually, and reading out all sensors individually.
- **Level 2:** This level consists of functional tests, patterned after the tests done on S, C, and M individually from Dec 03 – May 04.

Level 2 functional tests include the following tasks.

- Mix gas in Box S,
- Fill gas via Box C,
- Circulate via manifolds,
- Vent via Box C, and
- Readout of all sensors at all points of functional testing.

2 Equipment

A list of the equipment required in the test, and the institute responsible for supplying it, can be found in Table 2. [I (Drew) imagine that CERN has the gas hardware to hookup, but if need be I can probably bring some components from MIT—please advise if this is necessary.]

| Item | Supplier |
|--|-----------------|
| <i>Test Components</i> | |
| UGBC, UGFV, UGM, UGBS, and USCM | Rome |
| Box-C canister | MIT |
| Box-C V6, V18, P4 | MIT |
| Monitor tube dummy board | MIT |
| Manifold segments | CERN |
| TRD Dummy volume | CERN |
| <i>Gas components</i> | |
| Swage components for hookup of S, C, and M | <i>CERN</i> |
| Ar, CO ₂ gas bottles | CERN |
| Adjustable pressure regulators (~ 300 bar) | CERN |
| <i>Electric/electronic components</i> | |
| Glenair connectors | MIT |
| Laboratory DC power supply | CERN |
| Power supplies for crate | Rome |
| UG-crate | Rome |
| Computer interface to UGBC, USCM | Rome |
| Manual control box | MIT |
| DB9 cable (if necessary) | MIT |

Table 1:

3 Procedure

General Note: For each step taken, all TRD gas system data should be logged by the control computer. This accomplishes the goal of simplifying the procedural instructions and also allowing for arbitrary cross-checks of systems in different areas.

The setup and connections for Box C and Box S will be identical to those indicated on the TRD Gas Summary of 4 April 2003, which is available on the AMS webspace. Manifold connections and setup are as yet undefined.

The control program, to be written by F. Spada, will log data in a format compatible with the TRD Gas System monitoring program written by Prof. Qi Li of Southeastern University. This allows for an easy visual display of the data. The data file format is described in the appendix.

Because the purpose of the test is to validate the hardware in near-flight conditions, all modules will be connected to the backplane, including the cold USCM, for the duration of the entire test.

3.1 Level 1 Test Protocol

In order to prevent damage to the apparatus as well as validate the correct function of the components in the simplest context possible, each electromechanical component to be tested will be actuated, individually, with no pressure applied to the system. Confirmation will be audible and, where applicable, by LED. The components in question include:

- Marotta MV197 valves in Box S
- Marotta MV100 valves in Box C
- Bürkert valves V8a and V8b in Box C
- Circulation pumps CP1 and CP2 (high/low speeds)
- Bürkert valves on the appropriate manifold segments

There are also several command combinations that are prohibited in hardware. We should then verify that we are **unable** to do the following:

- Simultaneously open V1a and V2a.
- Simultaneously open V10a and V2a.
- Simultaneously open V1b and V2b.
- Simultaneously open V10b and V2b.

Also, there are command combination that allow certain valves to be opened in one UGBC/S command. These, which should be tested, are:

- Simultaneously open V6a and V18a.

- Simultaneously open V6b and V18b.
- Simultaneously open V20a and V20b.

The following sensors should be read during the course of the Level 1 test. (Italics denote sensors for which open issues exist.)

- The GP:50 pressure sensors P1a and P1b
- Temperature sensors T1a and T1b
- *The Kulite pressure sensors P1c and P1d*
- The GP:50 pressure sensors P2a and P2b
- Temperature sensors T1a and T1b
- *The Kulite pressure sensor P2c*
- The GP:50 pressure sensor P4
- The GP:50 temperature sensor T4
- *The CO₂ sensor.*
- Pressure sensors on the manifolds, PMiA and PMiB.
- The Dallas sensors D1a, D1b, D2a, D2b of Box-C

A successful test would involve two series of successful reads of each sensor. This confirms correct operation and repeatability with the flight setup.

3.2 Level 2 Test Protocol

3.2.1 Mix Procedure

For the mixing procedure, we mirror the filling simulation done at the UGBS electronics test. We use the predefined command sequences used there.

1. **Xenon Fill Step:** Open V1a 1s, wait 5s, open V2a 1s, wait 5s, open V3a 40s, wait 10s
2. **CO₂ Fill Step:** Open V1b 1s, wait 5s, open V2b 1s, wait 5s, open V3b 40s, wait 10s, read P2a
3. **Empty Mix Volume:** Open V4a, V6a, and V18a 60s, wait 10s, read P2a
4. **Set to Ground State 1:** Open V2a 1s, wait 5s, open V3a 1s, wait 5s, open V4a, V6a, and V18a 60s, wait 10s, read P2a
5. **Set to Ground State 2:** Open V2b 1s, wait 5s, open V3b 1s, wait 5s, open V4a, V6a, and V18a 60s, wait 10s, read P2a.

The mix simulation consists then of the following sequence.

1. Empty Mix Volume
2. Set to Ground State 1
3. Set to Ground State 2
4. Empty Mix Volume
5. CO₂ Fill Step
6. Xe Fill Step
7. Xe Fill Step
8. Xe Fill Step
9. Empty Mix Volume
10. Empty Mix Volume
11. Empty Mix Volume
12. Empty Mix Volume
13. Empty Mix Volume

If time permits, a test can be performed using the redundant mix configuration of Box S.

3.2.2 Fill, Circulation, and Vent Procedure

The redundancy in the circulation system is set up in parallel. Therefore, to test all of the components, at least two complete runs of this section will need to be performed. A sequence of steps that would constitute a complete run follows. (This assumes that the D mixing vessel is at nominal levels, ~200 psia.)

- FILL
1. Close V8a, V8b, V6a, V6b, V18a, V18b.
 2. Turn off CP1 and CP2.
 3. Open VMiA, VMiB, VMiC, and VMiD. (Open all segments.)
 4. Open V4a and V6a for 5 seconds.
 5. Read P4. (This to be done at test time rather than offline.)
 6. Check if P4 is in nominal range of 17-25 psi. If not, repeat steps 4-5 until P4 nominal.
- CIRC
1. Open V8a.
 2. Turn CP1 to high. Read P4 at test time and listen for motor sound.
 3. Log all system data at some interval TBD, for length TBD.

4. Turn CP1 to low. Read P4 at test time and listen for motor sound.
 5. Log all system data at some interval TBD, for length TBD.
- VENT
1. Open V18a for 60 seconds.
 2. Repeat until P4 at atmospheric pressure. (~ 15 psia.)

This stage is to be performed after a successful mixing stage. A redundant test would repeat the foregoing procedure with the “b” branch of the circulation system.

3.3 Tests on Manifolds

During the circulation, it will be possible to perform tests on the manifolds. Testing could include isolating individual segments manually and confirming expected operation via reads on PM*i*A and PM*i*B, if the setup permits.

4 Potential Testing Issues

Our preparations have identified a number of potential difficulties with the successful execution of the test.

- *Kulite sensors.* The Kulite sensors have V+ and V- outputs for the measurement of pressure. One output is held at a constant 620 mV while the other output gives 620 mV plus a pressure measurement. This means that the Kulite sensors cannot be read relative to the same ground as the GP:50 pressure sensors, which are referenced to the same ground as the excitation voltage. The implication, then, is that differential ADCs are required on the UGBS for successful readout of the Kulite sensors in the final configuration.
- *GP:50 Excitation Voltage.* The GP:50 requires an excitation of 10V, which is not currently supplied on the UGBC. As mentioned in the Box-C May electronics test report, the UGBC currently supplies for both the GP:50 pwr and ret lines 24V referenced to ground. Fixing this for the final versions will require board rework as well as the implementation of a new voltage source.
- *CO₂ Sensor Supply.* This requires not a 12V supply as on the current UGBC, but a 7.5–9V supply. Again, rework as well as a new voltage source is required.
- *Connections to UGBC.* The EM UGBC was built with a specification for a 37 pin connector JC3; MIT has in its specification a 25 pin JC3. Workarounds exist for this round of testing, but in later stages of development, agreement needs to be found.

| Field Name | Description | Values |
|------------|--|----------------------|
| Date | Date of measurement | YY:MM:DD |
| Time | Time of measurement (24 hr) | HH:MM:SS |
| P5 | Value of sensor P5 in psia | float |
| P4 | Value of sensor P4 in psia | float |
| TC1 | Value of Dallas sensor D1a | float |
| TC2 | Value of Dallas sensor D1b | float |
| V6a | Status of valve V6a | BOOL (0 or 1) |
| V8a | Status of valve V8a | BOOL |
| CP1 | On/off status of CP1 | BOOL |
| HI1 | High/Low status of CP1 | BOOL (0 low, 1 high) |
| V6b | Status of valve V6b | BOOL (0 or 1) |
| V8b | Status of valve V8b | BOOL |
| CP2 | On/off status of CP2 | BOOL |
| HI2 | High/Low status of CP2 | BOOL (0 low, 1 high) |
| Reserved | (Planned for CO ₂ fraction) | Undefined |

Table 2: Definition of fields for Box C logfile.

- *Connections for Dallas sensors.* Right now, the Dallas sensors in the Box-C canister and elsewhere need to be soldered to the USCM for a connection. A final connector designation seems necessary, either on the front panel of the USCM or elsewhere.

Procurement for 37-pin Glenair connectors is underway at MIT.

A Logfile Data Format

Data formats have been defined for Box S and Box C monitoring operations. Data is stored as tab-delimited text, with one value per column. From left to right, the formats are as in Tables A and A.

For the manifolds and sensors not covered by these files, a third logfile may be required, with specification to be set by Francesca Spada.

| Field Name | Description | Values |
|------------------|------------------------------------|----------|
| Date | Date of measurement | YY:MM:DD |
| Time | Time of measurement (24 hr) | HH:MM:SS |
| V1a | Status of valve V1a | BOOL |
| V1b | Status of valve V1b | BOOL |
| V2a | Status of valve V2a | BOOL |
| V2b | Status of valve V2b | BOOL |
| V3a | Status of valve V3a | BOOL |
| V3b | Status of valve V3b | BOOL |
| V4a | Status of valve V4a | BOOL |
| V4b | Status of valve V4b | BOOL |
| V10a | Status of valve V10a | BOOL |
| V10b | Status of valve V10b | BOOL |
| V20a | Status of valve V20a | BOOL |
| V20b | Status of valve V20b | BOOL |
| PXe | Pressure of Xenon vessel | BOOL |
| PCO ₂ | Pressure of CO ₂ vessel | BOOL |
| PDa | Pressure of D vessel | BOOL |
| PDb | Other measurement of D vessel | BOOL |

Table 3: Definition of fields for Box S logfile.

AMS-02 TRD GAS SYSTEM MANIFOLD ELECTRONICS TEST

CERN - Dec. 10-11, 2003

Alessandro Bartoloni, Carlo Bosio, Joseph Burger, Simonetta Gentile

A test of the engineering models of the control electronics for the AMS-02 TRD gas manifolds was made at CERN. One fivefold and one six-fold manifold were mounted in magnetic shielding boxes and equipped with pressure sensor cards. Card A0582B20 Rev. A A0581C22 S/N 007 (plug in back) was mounted on the 5-fold manifold with pressure sensors A, and card A0582B20Rev. A A0581B22 S/N 006 (plug on component side) was mounted on the 6-fold manifold with the B pressure sensors. Two cables were prepared with male 21 pin micro D connectors with 18" of AWG #26 wire on each end and central sections of AWG #26 shielded twisted pair cable, 4m and 6m long, respectively. The pressure sensors were connected to the cards with short lengths of twisted pair cable (2x2 – one each for power and signal) with connectors. The final version will use small circuit boards soldered to the pressure sensors instead of connectors. The collector end of each manifold was connected to an Argon bottle with a pressure regulator that could be adjusted to 0-5 bar. The segment lines on the manifold had labeled PVC tubes with their ends submerged in water. The tube for each pair of valves would bubble if both valves were open, and be still if either or both valves were closed.

Two UGM cards were mounted in a VME crate with an USCM which was used to control them.

For most of the tests, only 5 segments were read out per manifold, and one valve in the fivefold manifold was stuck shut.

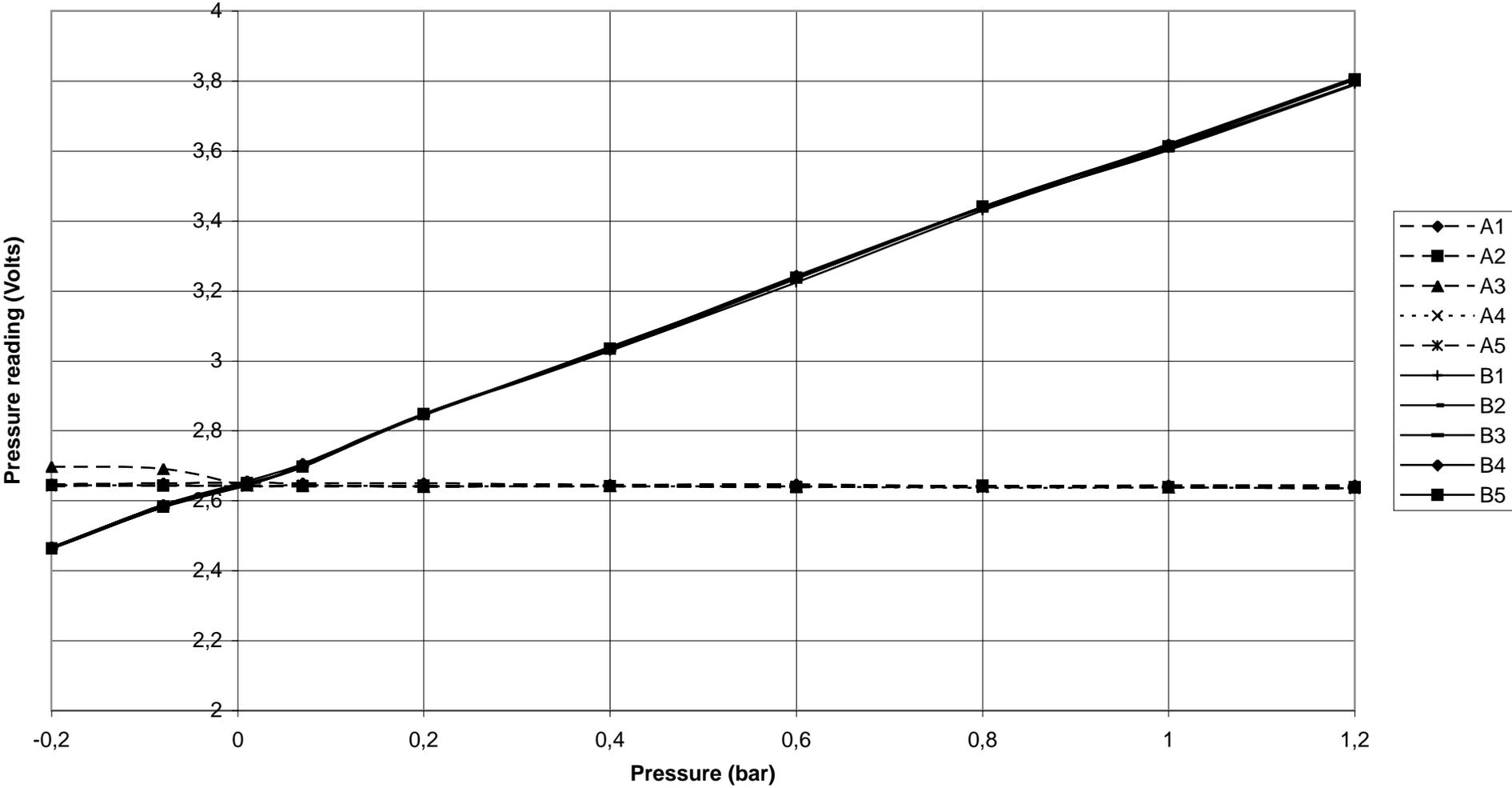
The first test consisted in operating all of the valves and checking the minimum pulse width which would work. These tests were done with 400-500 mb pressure supplied by the gas regulator. The pulse width was controlled by a 10 bit address.

1010000000 corresponded to the maximum pulse width of approximately 120 ms (as measured on an oscilloscope). All valves (except the defective one in the fivefold module) functioned down to a pulse width of about 10 ms (corresponding to the bit pattern 1000010000).

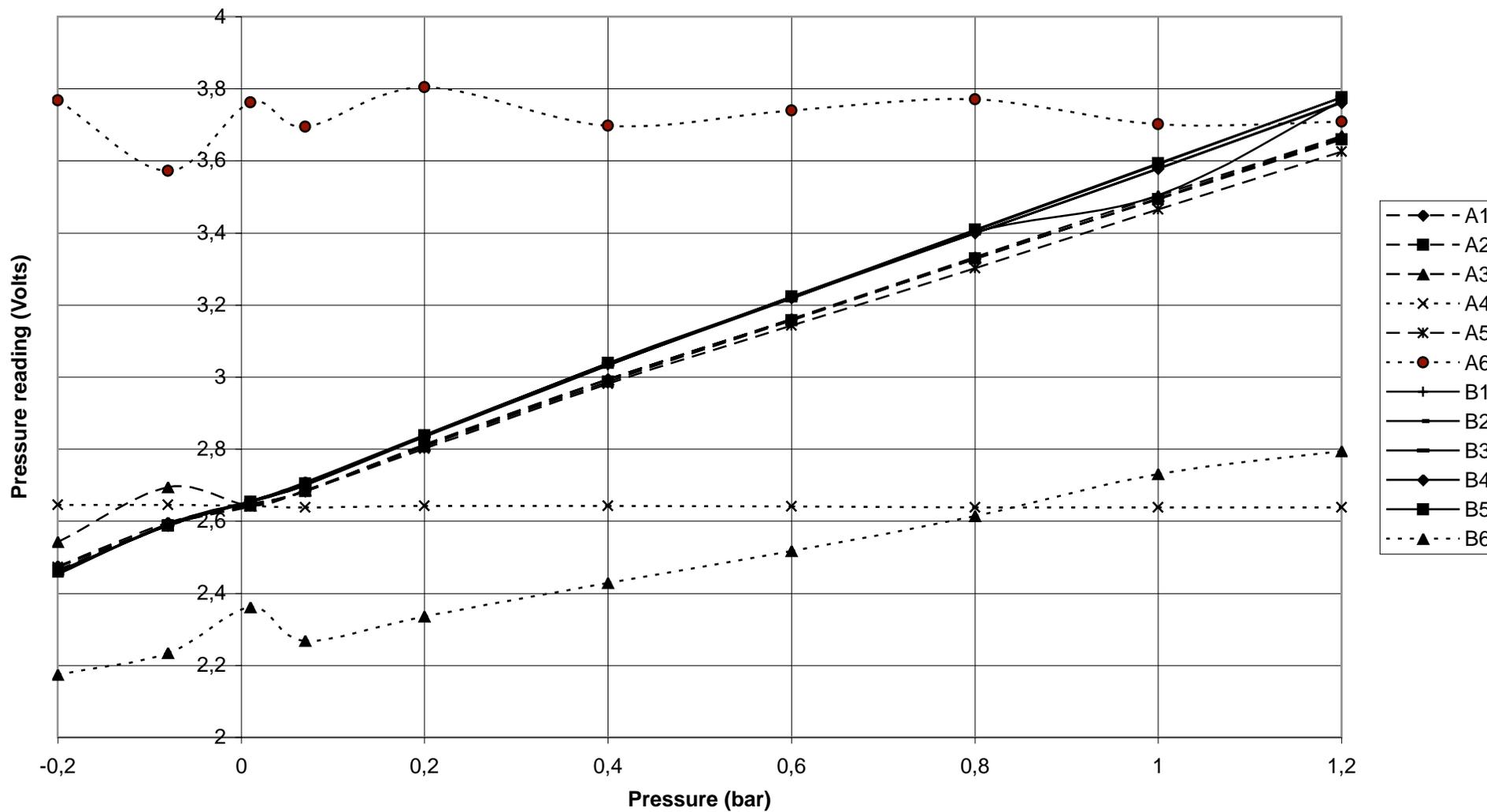
Then the pressure was varied, and pressure sensor readings were recorded for three configurations:

AC valves closed and BD valves open, which puts full pressure across the A sensors;
AC valves open and BD valves closed, which puts full pressure across the B sensors;
all valves open, which gives the pressure drop across the restrictions at the A and B pressure sensors. The results are shown in the accompanying plots, made for pressure differences of -0.2 bar to +1.2 bar) which indicate a sensitivity of about 1 mV/ mbar (1.08-1.24). The case of a leaky segment under vacuum connected to a working gas system corresponds to the 1.2 bar pressure. Normal operation, with a flow of 1 liter/hour per segment, would correspond to a pressure drop across the sensors of + (for the inputs) or – (for the outputs) about 50 mbar, corresponding to voltage differences of about 50 mV.

AC Valves Open, BD Closed



All Valves Open



AMS-02 TRD UGBS ELECTRONICS TEST ON ENGINEERING BOX S

CERN – Mar. 15-19, 2004

Alessandro Bartoloni, Carlo Bosio, Joseph Burger, Simonetta Gentile, Francesca Spada

A test of the engineering models of the control electronics for the AMS-02 TRD Box S was made at CERN. The Engineering Box S, equipped with 9 Marotta MV197 valves (V1a, V1b, V2a, V2b, V3a, V3b, V4a, V20a, V20b), four GP50 pressure sensors (P1a, P1b, P2a, P2b. [P2b was not functioning during the test]), and three Omega pressure sensors (Omega 1,2,3, which could be read out manually via a digital voltmeter). The Engineering Box S was connected via 37 pin connector J1 and 31 pin connector J3 to a UGBS card in a VME crate with a USCM used for control. Control was done from a Windows PC, running CAN_PC via an “EPP – AMSwire/canbus adapter box”. Pinouts for the cables are attached (UGBS_EBoxS.txt). The Engineering Box S did not contain gas tanks, but was connected to argon and CO2 bottles with mechanical pressure gauges and manual shutoff valves. Argon was used in place of Xenon for the tests.

The first test consisted of reading the two VP50's P1a and P1b, while changing the pressure in steps (by releasing small volumes of Ar or CO2 into the input lines of the Engineering Box S). Plots were made of VP50 pressure vs. the pressures read from the mechanical manometers on the bottles (plot attached – GP50s). At the same time. P2a was read out, as well as the three temperatures, T1a, T1b, and T2a.

The second test consisted in opening all the MV197 valves, one at a time, for one second, with no pressure applied to the system. All functioned and were connected properly (function was confirmed by hearing a click and seeing a LED on the line for the valve light up). The lines for the valves not installed (4b, 10a, 10b) were verified by the light diodes.

The third test was a filling simulation. Five command sequences were prepared:

1. Xenon Fill Step: (Open V1a 1s, Wait 5s, Open V2a 1s, Wait 5s, Open V3a 40s, Wait 10s, Read P2a)
2. CO2 Fill Step: (Open V1b 1s, Wait 5s, Open V2b 1s, Wait 5s, Open V3b 40s, Wait 10s, Read P2a)
3. Empty Mix Volume (Open V4a 60s, Wait 10s, Read P2a)
4. Set to Ground State 1: (Open V2a 1s, Wait 5s, Open V3a 1s, Wait 5s, Open V4a 60s, Wait 10s, Read P2a)
5. Set to Ground State 2: (Open V2b 1s, Wait 5s, Open V3b 1s, Wait 5s, Open V4a 60s, Wait 10s, Read P2a)

For the first try, it was not possible to open a valve for more than 8-10s, so “Open valve x for n x 10s” was replaced by “Open valve x max duration n times”.

The fill simulation consisted of the sequence

1. Empty Mix Volume
2. Set to Ground State 1
3. Set to Ground State 2
4. Empty Mix Volume
5. CO2 Fill Step

6. CO2 Fill Step
7. Xe Fill Step
8. Xe Fill Step
9. Xe Fill step
10. Empty Mix Volume
11. Empty Mix Volume
12. Empty Mix Volume
13. Empty Mix Volume
14. Empty Mix Volume

The pressure P2a was recorded each time.

Plots are attached (First Fill Exercise, to be compared with Manual Fill 15 March, 2004). When compared with a similar set of measurements made manually the day before, it was noted that the pressure rise per CO2 fill step was 50% higher. This was probably due to temperature differences (19.3 C on Monday, 24.8 C on Tuesday).

After these measurements, the opening time problem (in the software) was corrected, and the command sequences modified accordingly.

Then the third Omega pressure sensor was connected, and in subsequent tests, the three Omega sensors (measuring the same pressures as P1a, P1b, and P2a) could be read out with a DVM, through the 21 pin connector J2.

On Wednesday, the filling simulation was repeated under these conditions (T=22.6C). Plots are attached (Second Fill Exercise), including comparison of P2a and Omega 3 (plot Omega3 vs. P2a).

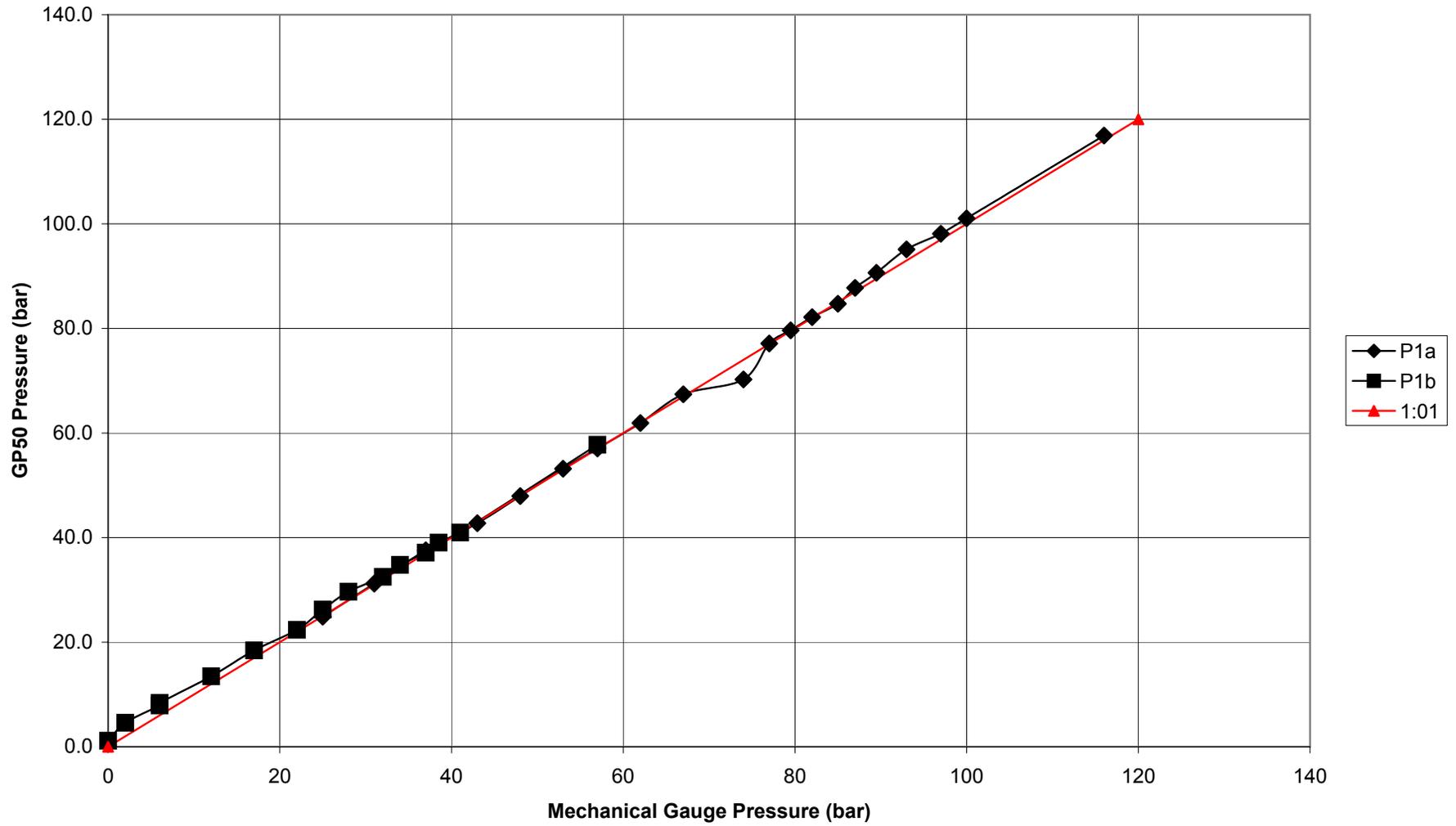
Then the P1a and P1b measurements were repeated, this time including Omega measurements. Plots attached (Omega1 vs. P1a and Omega2 vs. P2a).

The decay times for emptying the mixing tank, D, were the same for all tests, as plotted in Emptying Time Constant

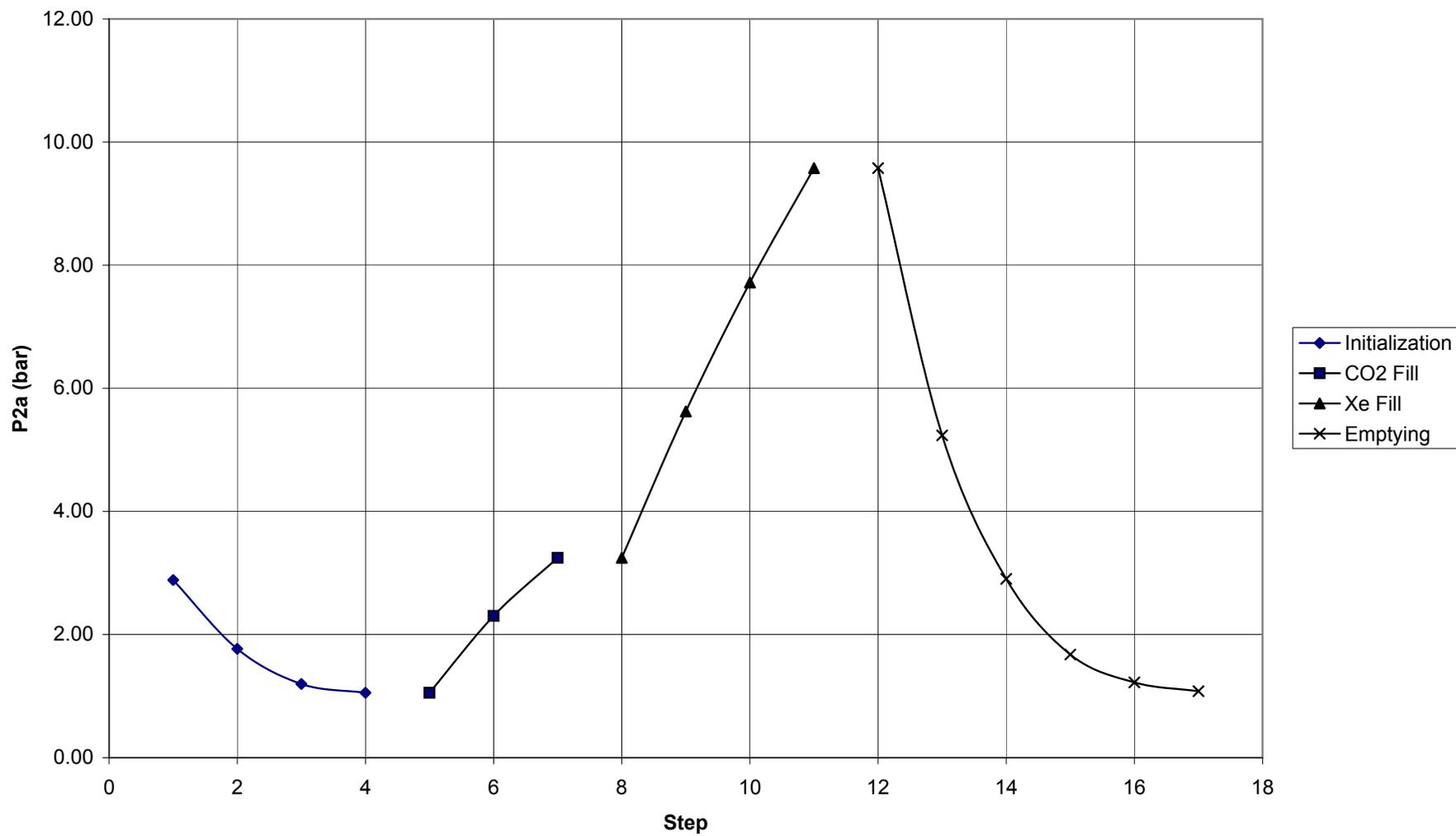
We also checked the minimum pulse which could open a valve. The valves could be pulsed between 1 ms and 67 seconds. We pressurized the mixing tank to 4.5 bar, and pulsed V4a, with a line going from the output to a water bubbler. Nothing happened for pulses of 1, 4, or 5 ms. For 6 and 8 ms, a click could be heard and gas seen escaping (no measurement of volume).

Next day, trials were made using the LeCroy protocol, with LeCroy Bus Commander or HV Pro Commander on a Linux laptop connected via the parallel port (EPP) and the "EPP – AMSwire/canbus adapter box". Valve 4a was successfully opened for 30 seconds, but pressure readings were unstable (50mV rms noise on the 0-5V signal). This was reduced to 5.8mV rms by grounding the laptop power supply correctly. Care should be taken for grounding on the gas system and its slow control.

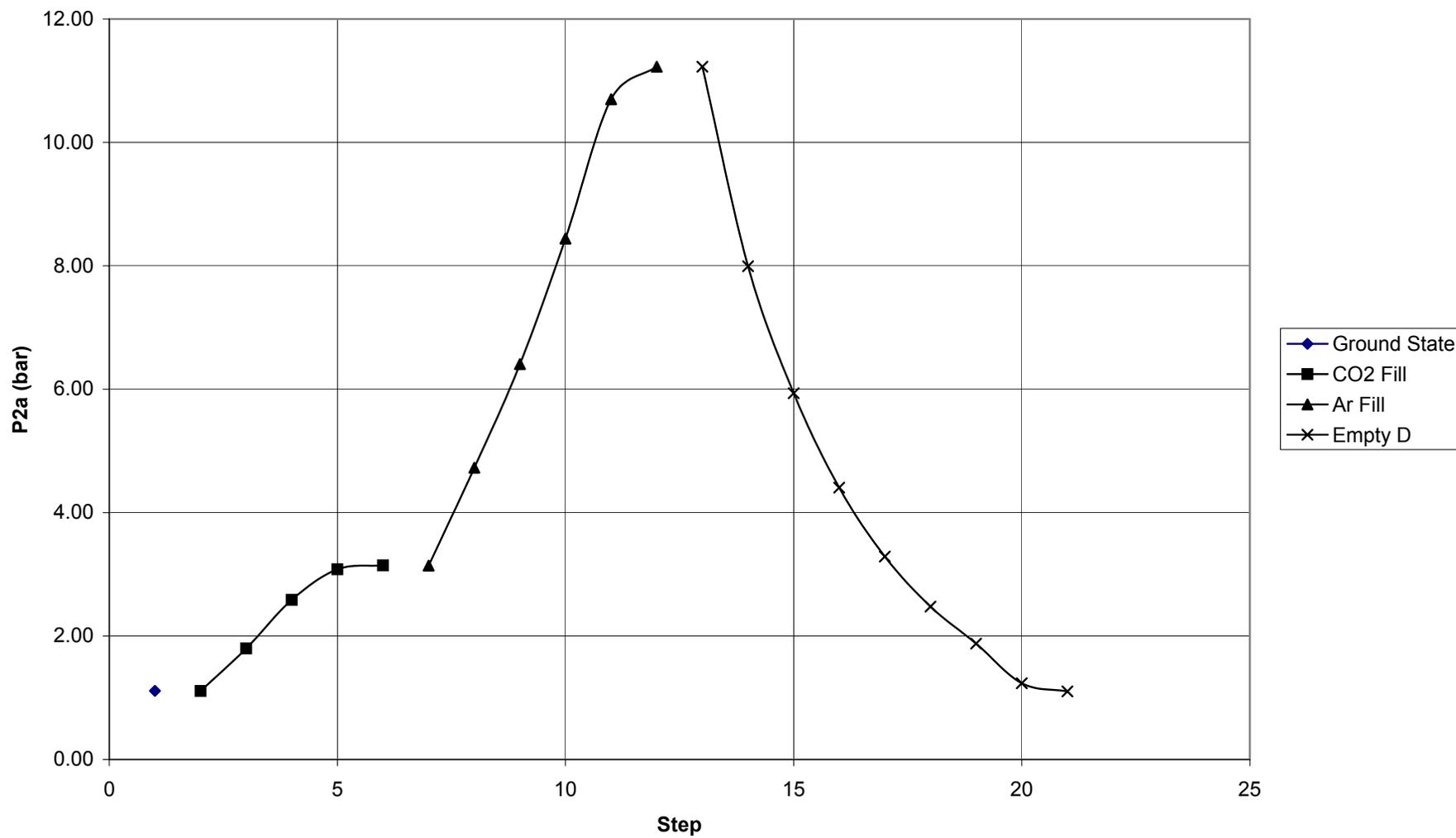
GP50s



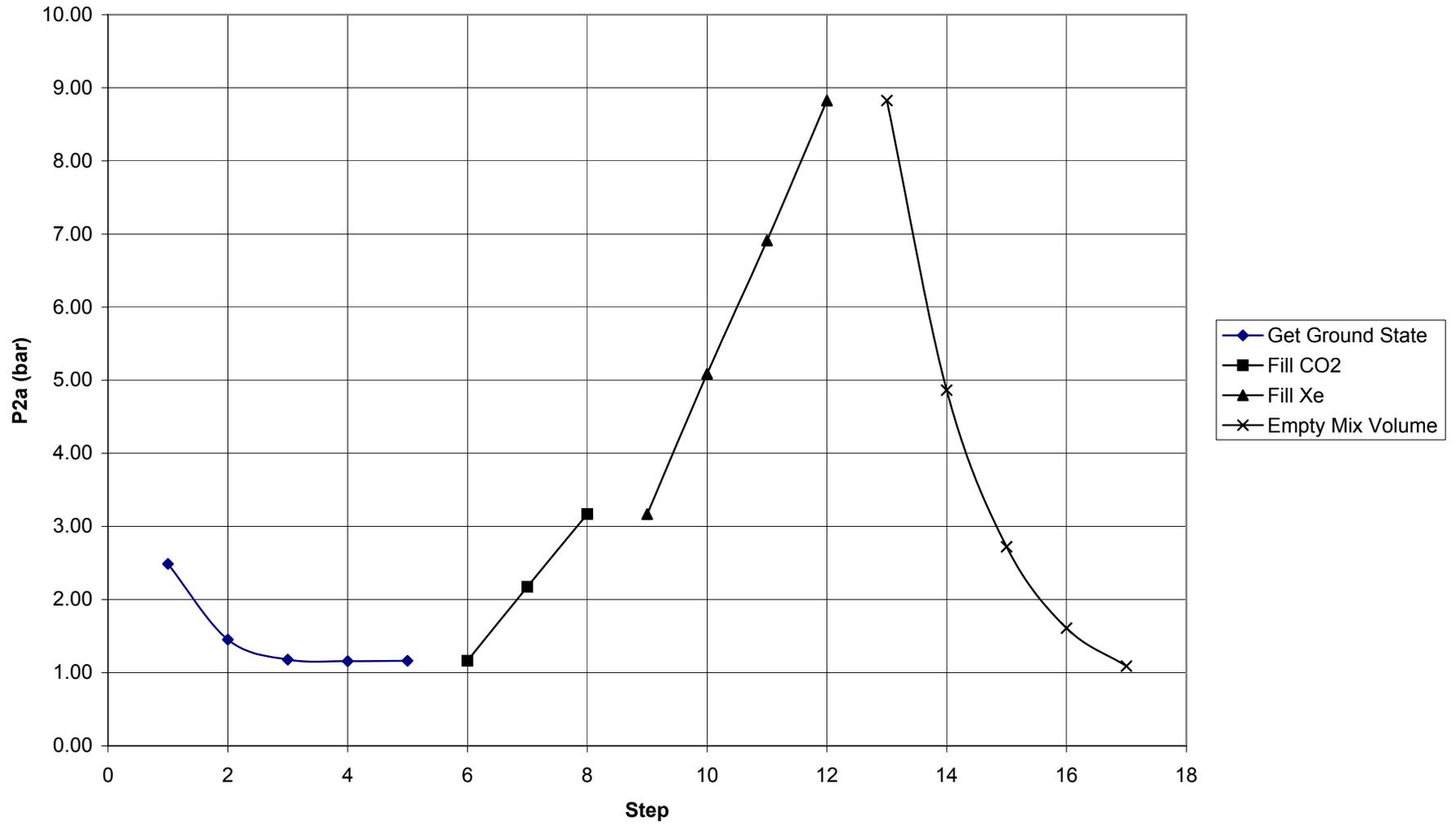
First Fill Exercise



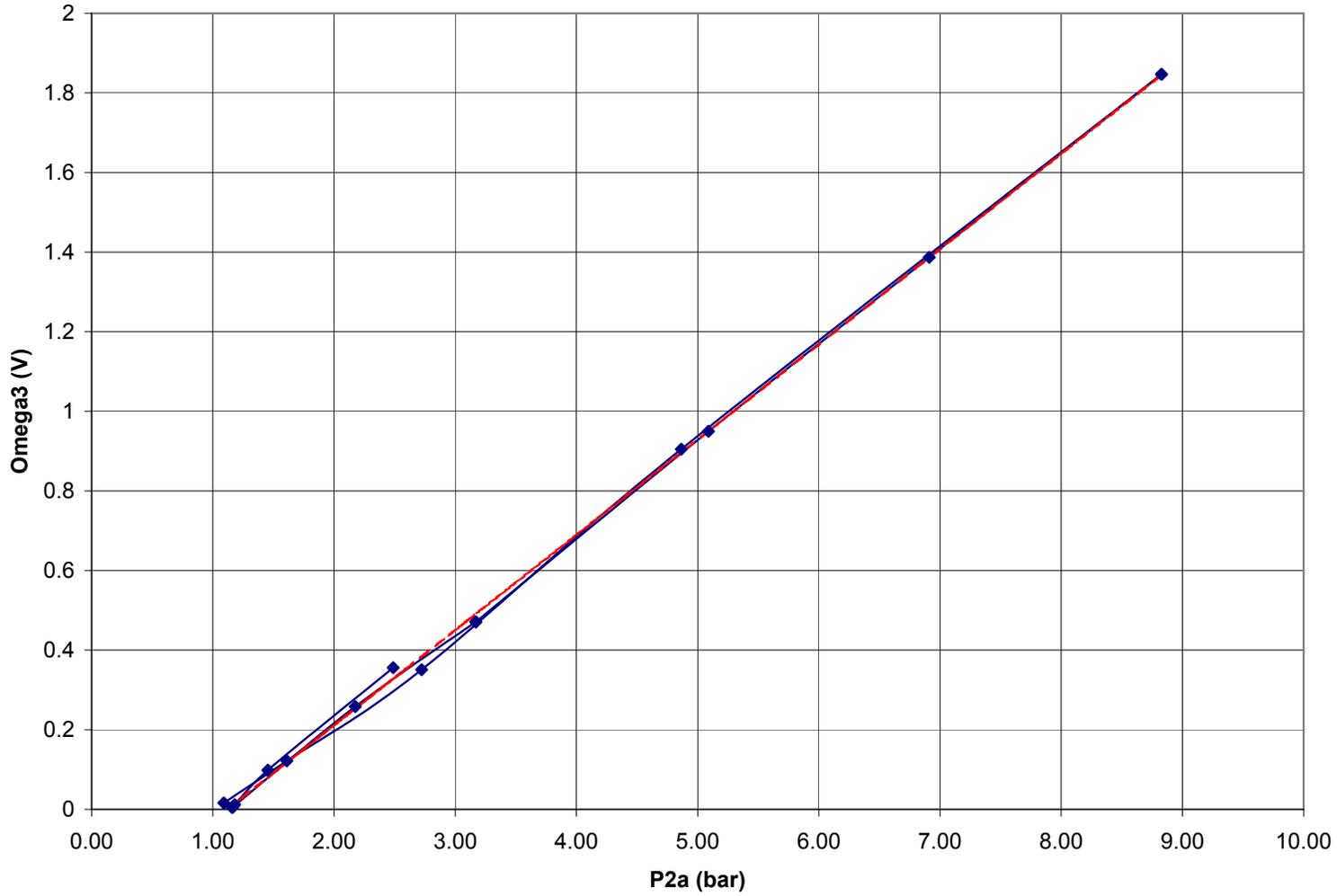
Manual Fill 15 March, 2004



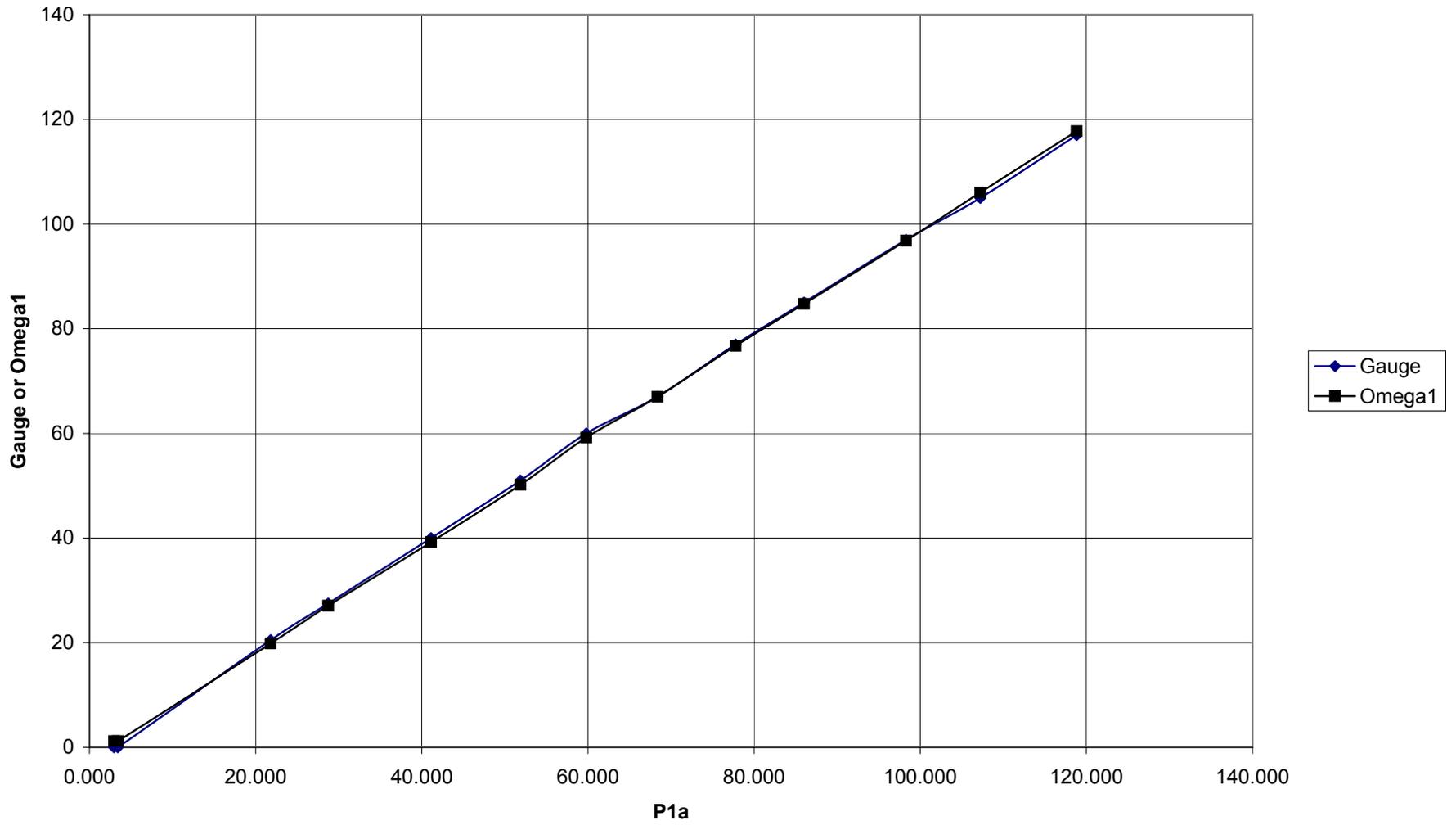
Second Fill Exercise



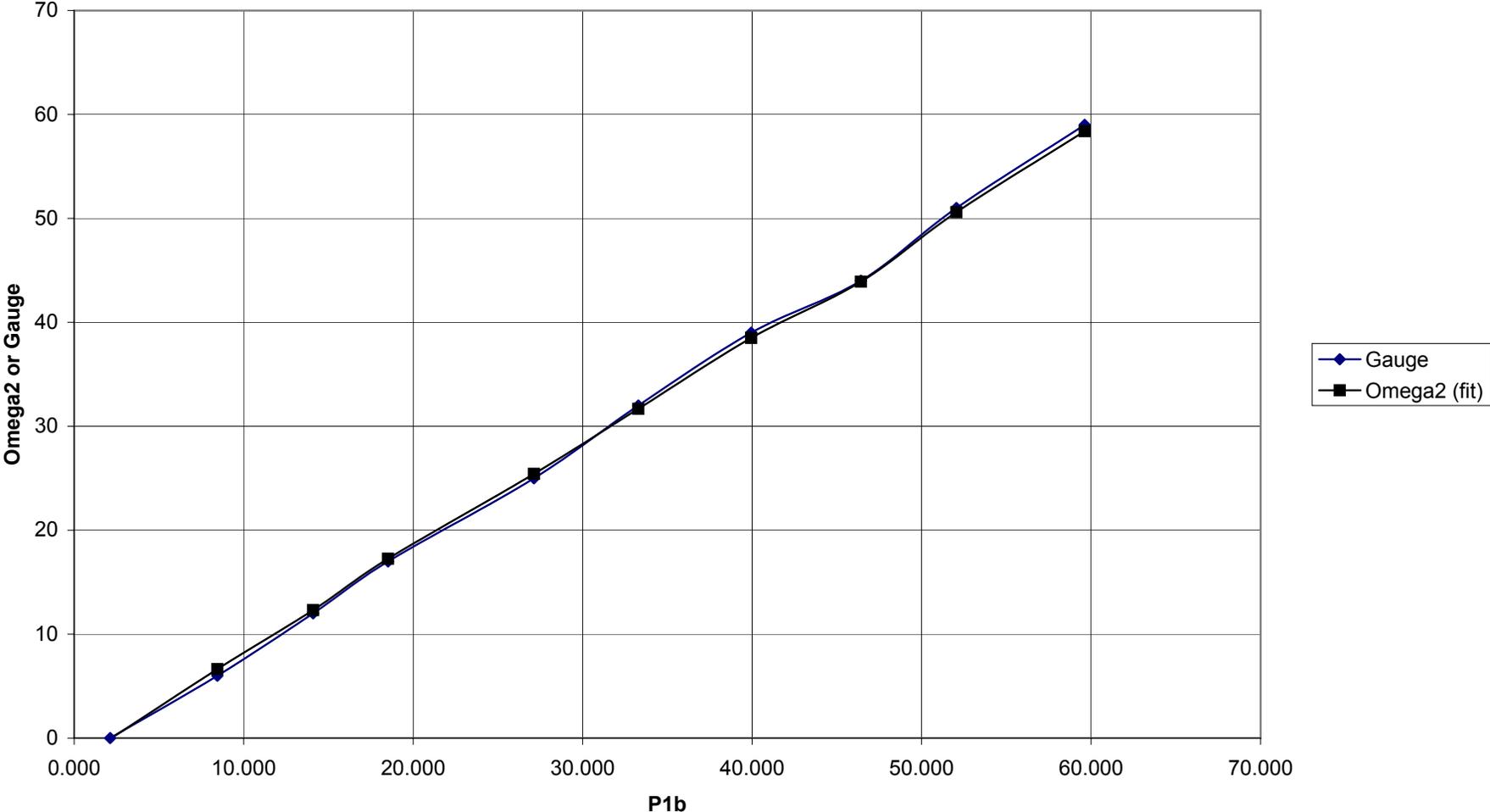
Omega3 vs. P2a



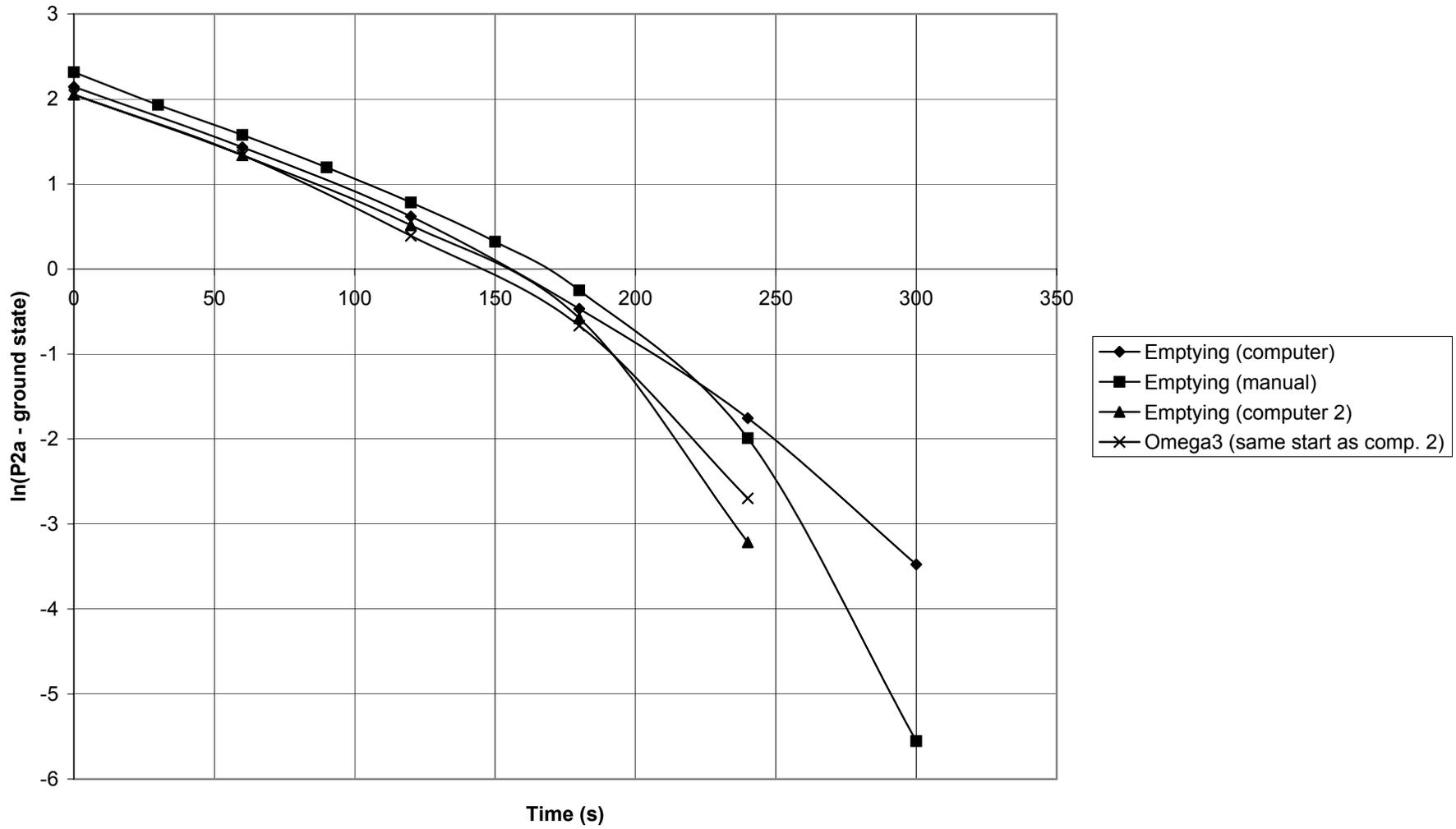
Omega1vs. P1a



Omega2 vs. P1b



Emptying Time Constant



AMS-02 TRD UGBC Electronics Test on Engineering Box-C

A. Bartoloni, C. Bosio, J. Burger, S. Gentile, F. Spada, A. Werner

June 7, 2004

1 Introduction

During the week of 17 May, tests were performed at CERN on the engineering models of the control electronics for the AMS-02 TRD Box-C. The engineering Box-C consists of two circulation pumps (CP1, CP2), two Bürkert flipper valves (V8a, V8b), four Marotta MV100 solenoid valves (V6a, V6b, V18a, V18b), one GP:50 0-25 psi pressure sensor, and one ndd spirometer. The control electronics consisted of an engineering UGBC, and two USCMs, one of which was unused for the test.

2 Tests Performed

The electronic tests were divided into three parts. The first two stages of testing validated the UGBC interface with the electromechanical components of Box-C. The last test involved reading the transit time of ultrasound in air.

The first part of the test validated the operation of the electromechanical components inside the Box-C canister. To do this, with the system in open circulation, we used the UGBC to run one of the circulation pumps with the appropriate V8 valve in either the open or closed position. Confirmation of proper operation was achieved via a bubbler on the outlet and, in some cases, examining the current draw on the power supply for the circulation pump.

The second part of the test validated the operation of the Marotta valves located outside of the canister.

The last part of the test was less a planned exercise than a problem-solving process. It was our first attempt to read out the ndd spirometer via USCM.

Setups used for the open and closed circulation tests are given in the test plan, [1].

3 Results

3.1 Open circulation

We performed an open circulation test twice, once using the program `can_pc` [2], and once using Linux-based graphical interface software written by F. Spada.

Prior to performing the first test, we checked the setup for proper operation using a manual control box built at MIT. While there was audible evidence of proper pump and valve operation, we failed to see the proper output on the bubbler. This problem turned out to be due to a bad seal on the canister. Because sealing the canister would have been a time-consuming proposition, we left the canister open and sent both pump outputs to a T, which then went to the mechanical pressure gauge P5 and the bubbler.

After this was in place, we were able to register output on the bubbler, but only noticed a reduction (not an elimination) in flow when either pump was on but both valves were closed. This was traceable to bad hose crimps on the Bürkert valve block and on the inputs to the circulation pumps. The crimps were removed, and the joints were temporarily secured with cable ties.

After validating the operational setup manually, the details of the interface between the UGBC and Box-C had to be worked out. The pinouts of the Rome UGBC and the MIT box were mostly compatible, with the following exceptions:

- The GP:50 excitation voltage provided by the UGBC was incorrect. Both JC1.04 and JC1.14 (excitation return and power, respectively) were held at 24V with respect to UGBC ground. Instead, JC1.14 and JC1.04 should be held at a relative potential of 10V, with JC1.14 having positive and JC1.04 having negative polarity. This was corrected by connecting the pressure sensor to the MCA power supply, which was otherwise unused.
- The magnitude of the CO₂ sensor power supply was incorrect. Rather than being at 12V, JC1.08 should have been at 7.5-9.0V. This was corrected by using a laboratory power supply for the CO₂ power.
- There was a conflict in the number of pins on the male connector JC3 supplied by MIT and the number on the female connector on the UGBC; they numbered 25 and 37, respectively. The pinouts both agreed until pin 25 inclusive; after this, the UGBC devotes 12 pins to valve status signals from the four Marotta valves. Rome provided a male 37 pin Glenair cable that was manually wired to the Box-C terminal blocks.

Using the `can_pc` program, a power-up of the UGBC was attempted. We were able to set CP1 to the low speed (as observed through the current draw on the 24V power supply) and open and close V6a (as observed through a clicking noise). Following this, we executed the following procedure, which roughly follows that detailed in §3.1 of the test plan. All steps execute successfully.

1. Read P4.

2. Set CP1 to speed “low”.
3. Close V8a.
4. Open V8a.
5. Read P4. Noticed readings in step 1 were incorrect.
6. Close V8a.
7. Set CP1 to “off”.
8. Read P4.
9. Open V8a.
10. Set CP1 to speed “high”.
11. Read P4.
12. Set CP1 to speed “off”.
13. close V8a.
14. Read P4.
15. Set CP2 to speed “low”.
16. Open V8b.
17. Read P4.
18. Close V8b.
19. Read P4.
20. Set CP2 to speed “high”.
21. Open V8b.
22. Read P4.
23. Set CP2 to speed “off”.
24. Close V8b.

The next day (Tuesday 18 May) we used a Linux-based graphical software package written by F. Spada to duplicate the open circulation test. In this program, the sensor denoted P4 in the test plan was denoted P3. In this document, we follow the convention of the test plan throughout.

Before beginning the test, the gaskets used to seal the Box-C canister were trimmed, and a reasonable seal was obtained. While the vessel was not entirely leaktight, we were able to gauge proper operation of the apparatus with the manual control box, and thus proceeded with our tests. The following steps were followed, all of which executed successfully:

1. Check P4 pressure and temperature. (*Software temperature/pressure calibration incorrect*).
2. Set CP1 to speed “low”.
3. Open V8a.
4. Check P4 pressure and temperature.
5. Close V8a.
6. Set CP1 to speed “high”.
7. Open V8a.
8. Read P4 pressure and temperature.
9. Close V8a.
10. Turn CP1 off.
11. Read P4 pressure.
12. Set CP2 to speed “low”.
13. Open V8b.
14. Check P4 pressure.
15. Close V8b.
16. Set CP2 to speed “high”.
17. Open V8b.
18. Read P4 pressure.
19. Close V8b.
20. Turn CP2 off.

A summary of the pressure/temperature readings taken during this test can be found in the appendix.

3.2 Closed circulation

After completing the open circulation test, the system was placed in Setup 2 (see §2 of the test plan). The steps followed mostly parallel those in §3.2 of the original test plan, except we decided to skip those steps that pertained to the pumps and V8 valves; their operation had been repeatedly validated. For P5, we used a mechanical manometer.

To verify proper filling, we listened for a clicking sound accompanied by an increase in the pressure displayed by the manometer. This was followed in all cases by a crosscheck of P4. Venting was verified by a clicking sound accompanied by a decrease in the displayed pressure and activity on the bubbler. All steps indicated below executed successfully.

1. Both gas regulators set to 0.3 bar overpressure.
2. Open V6a, wait 20 seconds, close V6a.
3. Read P4 pressure.
4. Open V18a, wait 60 seconds, close V18a.
5. Open V6b, wait 20 seconds, close V6b.
6. Read P4 pressure.
7. Open V18b, wait 60 seconds, close V18b.
8. Open V6a and V18a simultaneously for 5 seconds.
9. Open V6b and V18b simultaneously for 5 seconds.

3.3 Spirometer and other electronics

Our first attempt to communicate with the spirometer was through the `can_pc` program. The spirometer itself is described elsewhere, [4]. The spirometer accepts commands and sends data via an RS-232 serial interface, 19200 baud, 8-N-1. The appropriate communication lines are represented on the UGBC pinout, where level conversion occurs; the signals are then routed via the backplane to the USCM, where they are directly input to the USCM.

The USCM itself routes the RxD and TxD signals (having been converted to TTL levels) directly to the 80C390 microcontroller. According to Hans-Bernhard Bröker¹, the data is stored in a 256 byte circular buffer that is cleared before before a read sequence begins.

This fact may help to explain some of the puzzling behavior that we observed when using `can_pc` to read the spirometer. We were interesting in sending two commands to the spirometer: `START` and `STOP`. Commands take the form of a four byte sequence that begins with `Ctrl-B` (ASCII 0x02); `START` is hex 02 4D 30 31 (M01 for the final 3 bytes in ASCII), `STOP` is hex 02 4D 30 30 (M00).

¹III. Physikalisches Institut, RWTH, D-52056 Aachen, Germany

Our first attempts involved use of the `serial` and `terminal` commands. The `serial` command did not function correctly due to the nonprinting nature of the Ctrl-B character. The `terminal` command did not work due to reasons which are still not completely clear.

We were ultimately successful reading data through the debug console. The debug console uses one of the USCM serial ports as a TTY interface to execute low-level commands to the USCM. By typing the control sequence (Ctrl-B M 0 1) into the debug console, we were able to see the spirometer information transmitted exactly as we would expect: a repetitive string of seven bytes, the first being the Ctrl-B character (represented on the terminal as a “smile face”), the second being one of the characters “0”, “1”, “2”, or “3”, the next four being a hexadecimal number with a base 10 value in the range of 16,000–17,000, and the last being a single hexadecimal digit.

After having started the data transmission via the monitor, we were able to issue commands via the terminal. The terminal also displayed a corrupted version of the data that was viewed through the monitor; while we generally viewed the same characters, they were rearranged; the same characters had a tendency to appear in groups, with approximate periodicity of a few hundred characters.

An exchange of emails and conversations with Bröker and Klaus Hangarter² yielded several suggestions for getting the `serial/terminal` interface to work. This was largely based off of the idea that the sharing of the debug console with the CO₂ TTY (via the `ascii` command) could have been interfering with the transmission of data. The major suggestion was to use a configuration file that prevents the `ascii` command from modifying the RS-232 interface. The hypothesis that the monitor interface was to blame for the interference with the interface seemed to be disputed, though, by the absence of any letters resembling the `MON_90>` prompt in the interface; indeed, pretty much all of the text we saw in the terminal could have plausibly come from the spirometer.

Before attempting to generate and load a configuration file, we attempted to set aside both serial ports on the USCM for the user, and use only the CAN bus for the debug console. This was accomplished by executing a text file in `can_pc` with the following commands:

```
mb 28
1
+
1
.
md 3b
2
.
```

There was no change in our observed behavior after executing this series of commands.

²III. Physikalisches Institut, RWTH, D-52056 Aachen, Germany

After this, we began testing with the `xcan`³ package of software, with the assistance of S. Xu. We were able to read Dallas sensors without a problem. To communicate with the spirometer, we used a generalized communication program called `xcan_txrx`. This command takes a CAN ID followed by data, represented as space-delimited hexadecimal bytes, as command line arguments. In order to send serial data to the spirometer, the command sequence we followed (from the working directory in which the `xcan` binaries are located):

```
./xcan_txrx 68 01 90 00 41 07 <data>
```

We found this to be unsuccessful. Xu suspected difficulty with the firmware.

After this, we consulted with A. Lebedev, who reprogrammed the PROM. The EPROM and EEROM versions can be checked from the USCM monitor, via the `eprom` and `eerom` commands.

We used his low-level debug package `6` to send CAN commands. `6` is called from its own directory as follows:

```
./6 <8_byte_can_address> <number_of_bytes> <message>
```

`6` is included in a large tarfile that is maintained at CERN. We attempted to use a computer belonging to S. Gentile to execute the CAN commands. We successfully executed a “power flip-flop” command on the board (via `./6 68004E00 3 41 5 D4`) but were unable to produce a positive result when we attempted to communicate with the spirometer.

The canister was then moved to building 892, where we tested the spirometer with a computer/USCM belonging to A. Lebedev. We were able to communicate with the spirometer after changing the configuration file and then typing a carriage return via a computer terminal into each USCM serial port manually. The configuration file set aside Serial 1 as the debug console; Lebedev strongly recommended that such modification be reserved for the technical staff at Aachen and CERN and *not* be undertaken by the user.

After this series of actions, we were able to activate the spirometer and receive back data that was just as expected. The canister was left at 892 for further work/experimentation over the next day. During this time, A. Lebedev made further changes to the configuration file and wrote a data acquisition interface to the spirometer.

4 Comments (A. Werner)

During the test, we were able to verify the proper operation of the interface between the TRD gas system slow control and the electromechanical components of Box-C. There appears to be some discrepancy between the temperatures and

³Available: <http://ams.cern.ch/AMS/DAQ/JIMCAN/>

⁴The CAN ID reflects the fact that the Rome USCMs had been redesignated 4E and 4F in place of 90 and 91.

pressures that we read with the GP:50 and the values we would expect, however; a value of ~ 11.5 psia with all pumps off appears not to make much sense. Similarly, the temperature sensor, whose temperature values are rather sensitive to small changes in voltage, gave results ($\sim 32^\circ\text{C}$) that were inconsistent with the ambient temperature. This can probably be attributed to either a miscalibration of the GP:50 device, the difference between the test excitation voltage and the calibration excitation, or some DC error in the A/D conversion.

We were able, in the end, to satisfactorily read out the spirometer; however, in doing so, the difficulties of the interface became apparent. In particular, obtaining large ($\sim 7\text{K}$) amounts of data from the MCA reliably and regularly will be a new test of the limits of the USCM serial buffer and the interface with the JMDC.

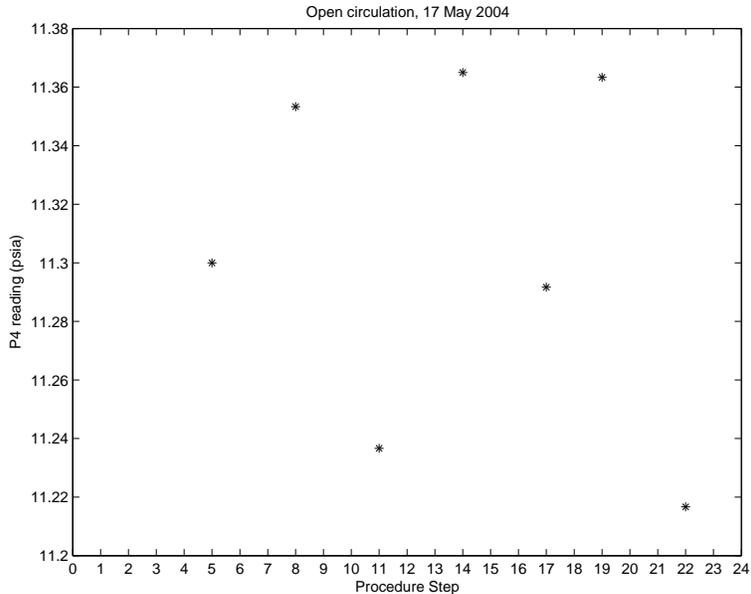


Figure 1: Pressure readings for open circulation tests with `can_pc`, 17 May 2004.

Appendix

A Results of Circulation Tests

The pressure readings for the open circulation tests of 17 and 18 May are shown in Figures A and A, respectively. All voltage readings were taken via UGBC; the readings were converted to pressures by using the final calibration of 17 Jun 03 by GP:50 for pressure sensor with serial number 702838.

The given values are, except in three cases, the average of three measurements. Those measurements that were taken with `can_pc` were relatively free of noise (< 5 mV) while those taken via the laptop computer appeared somewhat less stable. This could, as in the UGBS electronics test, be the result of grounding problems.

The measurements of the temperature we made with the F. Spada software are summarized in Table 1. To convert the voltage measurements to temperatures, we used the data provided by GP:50 on their final calibration under the category “RTD Calibration Data” to perform a three-point least-squares fit.

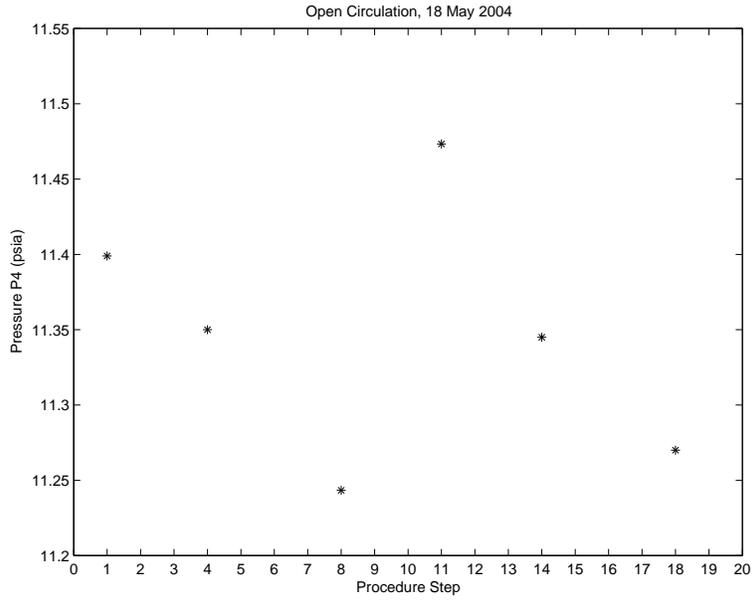


Figure 2: Pressure readings for open circulation tests with F. Spada software, 18 May 2004.

| Voltage (V) | Temperature (C) |
|-------------|-----------------|
| 2.475 | 31.15 |
| 2.487 | 32.52 |
| 2.483 | 32.06 |
| 2.488 | 32.63 |
| 2.492 | 33.09 |

Table 1: Results of repeated temperature measurements in open circulation. Fit equation used: $T = 114V - 251$.

B Notes on the Spirometer

B.1 Updating USCM Firmware and Configuration File

From Alexei Lebedev.

1. Make sure you have correct version in PROM and in EEROM of USCM:

```
MON_61> eprom
```

```
USCM3.3 Multitask System V3.5 built 24-Nov-2003 11:42:56 in ROM
type H for help,
<TAB> to list available commands or complete a started key,
G0 to start peripheral read out
```

```
CANBUS> USCM3.3 canIO task-2 v4.6 built 24-Nov-2003 11:42:56
mod-ID = 0x61 prog/data : 005FC0/003000, upc: 0004E66B69
```

```
MON_61> eerom
```

```
USCM3.3 Multitask System V3.6 built 24-Nov-2003 11:42:56 all in EEROM
type H for help,
<TAB> to list available commands or complete a started key,
```

```
PERIPHS> USCM3.3 Peripherals Task 2 V1.0 built 24-Nov-2003 11:42:56
CANBUS> USCM3.3 canIO task-2 v4.6 built 24-Nov-2003 11:42:56
mod-ID = 0x61 prog/data : 026025/003000, upc: 0004E69409
EE_UHVG> USCM3.3 User Idle Task V1.0 built 24-Nov-2003 11:42:56; XRAM @ 014000
```

```
MON_61>
```

2. How to convert *.cfg file into *.hex:

```
[lebedev@PCAAL02 CAN]% make m61-gas.hex
./cfg_gen m61-gas.hex < m61-gas.cfg 2> m61-gas.log
```

3. How to load software and config file into EEROM:

```
[root@PCAAL02 CAN]# load aeerom.hex 61
Usage: load <filename> <USCM_ID> [<JMDC_ID>] [<Printout Level>]
File 'aeerom.hex' opened
```

```

File checking...
Waiting for reboot...Done
Waiting for erase sector 0 .....
Start loading...
5337 line(s) read
File 'aeerom.hex' closed
validate OK:      adr = 20000, end = 34BE5, chksum = 63E4
LOADING SUCCEEDED.
Waiting for final reboot...Done

```

```

[root@PCAAL02 CAN]# load m61-gas.hex 61
Usage: load <filename> <USCM_ID> [<JMDC_ID>] [<Printout Level>]
File 'm61-gas.hex' opened
File checking...
Waiting for reboot...Done
Waiting for erase sector 7 .....
Waiting for erase sector 8 .....
Start loading...
409 line(s) read
File 'm61-gas.hex' closed
validate OK:      adr = 38000, end = 3A7A8, chksum = C4FF
LOADING SUCCEEDED.
Waiting for final reboot...Done
[root@PCAAL02 CAN]#

```

4. Verify the USCM "status":

```

[root@PCAAL02 CAN]# p 61
err = 0000
constant_01: 01
ROM version: 23
running_ver: 24
USCM_status: 1C
    D3: executing via EEROM
    D4: config CKS ok.
    D5: EEROM program CKS ok.
logical_ID: 61
newborn_ID: 61
something: 05
[root@PCAAL02 CAN]#

```

B.2 Configuration File Used

```

# This is a preliminary example configuration file to show what this
# might finally end up looking like:

```

```

# The file is divided into sections:
[General]
# These lines are the configuration block header. They should probably
# be moved into the generator (--> "No user-serviceable parts inside").
CodeBlockHeaderJump=0x02.03.8080 ; Magic cookie
CodeBlockHeaderStart=0x01.03.8000 ; Start address of Data block
CodeBlockHeaderEnd=0x01.03.A7A7 ; End address of data block
; NOTE: Cfg-Gen will replace value!
CodeBlockHeaderReserved=0x00.00.00.00 ; make next entry start on nice address

# A comment line to appear at the start of the config file, mainly for
# double-checking the correct config file was loaded into a USCM.
HeaderLine0="USCM3.3 Configuration for Module 0x61 built 30-Jan-2004 15:40:00"

# Make sure you don't change the length of anything before it!
# The position of the "V3.5" string in the line is referred to by the
# USCM code.
# HBB FIXME: this had better be moved into the generator program...
# EEROM versions other than the one name here will reject this config file:
HeaderLine1="Referring to EEROM program version V3.6"

[User Task]
TaskNumber=0 ; 0 = idle, 1 = UHVG task
PromptString="EE_UHVG"

[Module Type]
Type=1 ; TBD: what this may actually mean

[Serial Ports]
;Console = 0 ; use port 1 as the debugger console
Console = 1 ; use port 1 as the debugger console
# FIXME: special handler to create actual status byte from several config file
# entries?
;ReservedForUser = 0x00 ; use port 0 (bit # --> 1) for User I/O (like in StarTra
cker)
ReservedForUser = 0x01 ; use port 0 (bit # --> 1) for User I/O (like in StarTra
cker)
;BinaryMode = 1 ; Make port 0 use raw binary I/O
BaudRate0 = Baud(0,19200) ; Baud Rates for both ports
BaudRate1 = Baud(1,19200)

[CAN_Bus]
ValidForModuleNumber=0xff ; --> Only modify CAN configuration if
; this file is used with module # 0x3a
; not specified --> 0xff --> universal

```

```

LogicalAddress=0x61          ; Logical address of this USCM
                             ; not given --> 0xff --> Logical:=Newborn ID
CAN_register0 = 0x00        ; these may go away --- overrides for some CAN
CAN_mask3 = 0x7f.ff.ff.08  ; controller register settings.

JmdcAddress0 = 3           ; Note: changing these may not be
JmdcAddress1 = 2           ; useful at all...
JmdcAddress2 = 1
JmdcAddress3 = 0

[Dallas]
TurnOnDallasReading = 1    ; 0: disable Dallas readout globally
UseBroadCasts = 0         ; Reading out all in parallel?
BroadcastMax = 4          ; If not: how many in parallel?
ScanForSensors = 1       ; 0: don't search for sensors --> use config table

; Sensor = {"on-b 81 ", 0x10.D7.79.18.00.08.00.76, 1, 1}
Sensor={
    "on-b 61"              ; settings for one sensor
    0x00.00.00.00.00.00.00 ; the name of this sensor
    1                      ; its chip ID
    1                      ; the Dallas bus it is on
    1                      ; pre-scale factor / priority setting
}

#TBD: maybe the names should be changed to Sensor0 ... Sensor255 to
#make it easier to position to a given sensor when editing this file?

[DallasSorting]
Entry=0x11
Entry=0x10
Entry=0x0f
Entry=0x0e
Entry=0x0d
Entry=0x0c
Entry=11
Entry=10
Entry=9
Entry=8
Entry=7
Entry=6
Entry=5
Entry=4
Entry=3
Entry=2
Entry=1                      ; #1 must always be first?

```

```

[ADC]
SortingList={
    1, 2, 3, 4, 5, 6, 7, 8
    9,10,11,12,13,14,15,16
    17,18,19,20,21,22,23,24
    25,26,27,28,29,30,31,32
}

DifferentialList={                ; one entry per ADC chip (== 4)
    0,0,0,0                        ; 0 means normal mode
}

Names={
"LOGADC01"
"LOGADC02"
"LOGADC03"
"LOGADC04"
"LOGADC05"
"LOGADC06"
"LOGADC07"
"LOGADC08"
"LOGADC09"
"LOGADC10"
"LOGADC11"
"LOGADC12"
"LOGADC13"
"LOGADC14"
"LOGADC15"
"LOGADC16"
"LOGADC17"
"LOGADC18"
"LOGADC19"
"LOGADC20"
"LOGADC21"
"LOGADC22"
"LOGADC23"
"LOGADC24"
"LOGADC25"
"LOGADC26"
"LOGADC27"
"LOGADC28"
"LOGADC29"
"LOGADC30"
"LOGADC31"
"LOGADC32"

```

```
}

# DAC section is there, but empty:
[DAC]

SortingList={
    01, 02, 03, 04, 05, 06, 07, 08,
    09, 10, 11, 12, 13, 14, 15, 16
}

DefaultsList={
    0x00.00
    0x00.00
}

Names={
    "LOGDAC01"
    "LOGDAC02"
    "LOGDAC03"
    "LOGDAC04"
    "LOGDAC05"
    "LOGDAC06"
    "LOGDAC07"
    "LOGDAC08"
    "LOGDAC09"
    "LOGDAC10"
    "LOGDAC11"
    "LOGDAC12"
    "LOGDAC13"
    "LOGDAC14"
    "LOGDAC15"
    "LOGDAC16"
}
```

```

}

[UHVG]
# Note that this section will only be used if this USCM was configured
# in the [User Task] section to be using the UHVG-specific implementation
# of a user task.
NumMHV = 28      ; 2* #(chips/uhvg) * #(sides/chip)

Names={
  "broad"          ; special entry

  "M1C1SA", "M1C1SB", "M1C2SA", "M1C2SB", "M1C3SA", "M1C3SB"
  "M1C4SA", "M1C4SB", "M1C5SA", "M1C5SB", "M1C6SA", "M1C6SB"
  "M1C7SA", "M1C7SB"
  "M2C1SA", "M2C1SB", "M2C2SA", "M2C2SB", "M2C3SA", "M2C3SB"
  "M2C4SA", "M2C4SB", "M2C5SA", "M2C5SB", "M2C6SA", "M2C6SB"
  "M2C7SA", "M2C7SB"
  "M3C1SA", "M3C1SB", "M3C2SA", "M3C2SB", "M3C3SA", "M3C3SB"
  "M3C4SA", "M3C4SB", "M3C5SA", "M3C5SB", "M3C6SA", "M3C6SB"
  "M3C7SA", "M3C7SB"
  "M4C1SA", "M4C1SB", "M4C2SA", "M4C2SB", "M4C3SA", "M4C3SB"
  "M4C4SA", "M4C4SB", "M4C5SA", "M4C5SB", "M4C6SA", "M4C6SB"
  "M4C7SA", "M4C7SB"
  "M5C1SA", "M5C1SB", "M5C2SA", "M5C2SB", "M5C3SA", "M5C3SB"
  "M5C4SA", "M5C4SB", "M5C5SA", "M5C5SB", "M5C6SA", "M5C6SB"
  "M5C7SA", "M5C7SB"
  "M6C1SA", "M6C1SB", "M6C2SA", "M6C2SB", "M6C3SA", "M6C3SB"
  "M6C4SA", "M6C4SB", "M6C5SA", "M6C5SB", "M6C6SA", "M6C6SB"
  "M6C7SA", "M6C7SB"
}

UHVG_Numbers = {
  0
  0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
  1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1
  2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2, 2
  3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3, 3
  4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4, 4
  5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5, 5
}

Sides = {
  0
  0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
  0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1
}

```

```

    0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1,
    0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1,
    0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1, 0, 1,
}

MHV_Numbers = {
    0
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
    0, 1, 2, 3, 4, 5, 6, 0, 1, 2, 3, 4, 5, 6
}

ClockBits = {
    0x0f
    0x01,0x02,0x01,0x02,0x01,0x02,0x01,0x02,0x01,0x02,0x01,0x02,0x01,0x02
    0x02,0x04,0x02,0x04,0x02,0x04,0x02,0x04,0x02,0x04,0x02,0x04,0x02,0x04
    0x04,0x08,0x04,0x08,0x04,0x08,0x04,0x08,0x04,0x08,0x04,0x08,0x04,0x08
    0x08,0x10,0x08,0x10,0x08,0x10,0x08,0x10,0x08,0x10,0x08,0x10,0x08,0x10
    0x10,0x20,0x10,0x20,0x10,0x20,0x10,0x20,0x10,0x20,0x10,0x20,0x10,0x20
    0x20,0x40,0x20,0x40,0x20,0x40,0x20,0x40,0x20,0x40,0x20,0x40,0x20,0x40
}

DataBits = {
    0x00.ff
    0x00.01,0x00.02,0x00.01,0x00.02,0x00.01,0x00.02,0x00.01,0x00.02
        0x00.01,0x00.02,0x00.01,0x00.02,0x00.01,0x00.02
    0x00.04,0x00.08,0x00.04,0x00.08,0x00.04,0x00.08,0x00.04,0x00.08
        0x00.04,0x00.08,0x00.04,0x00.08,0x00.04,0x00.08
    0x00.10,0x00.20,0x00.10,0x00.20,0x00.10,0x00.20,0x00.10,0x00.20
        0x00.10,0x00.20,0x00.10,0x00.20,0x00.10,0x00.20
    0x00.40,0x00.80,0x00.40,0x00.80,0x00.40,0x00.80,0x00.40,0x00.80
        0x00.40,0x00.80,0x00.40,0x00.80,0x00.40,0x00.80
    0x01.00,0x02.00,0x01.00,0x02.00,0x01.00,0x02.00,0x01.00,0x02.00
        0x01.00,0x02.00,0x01.00,0x02.00,0x01.00,0x02.00
    0x04.00,0x08.00,0x04.00,0x08.00,0x04.00,0x08.00,0x04.00,0x08.00
        0x04.00,0x08.00,0x04.00,0x08.00,0x04.00,0x08.00
}

```

B.3 Data Acquisition Program

```

// file g.c
//
// to study TRD Gas Analyzer

```

```

//
// A.Lebedev - May-2004...

#include "uscmlib.h"

int P = 0;
int USCM_ID = 0x91;
int JMDC_ID = 0x00;

//-----

int main(int argc, char *argv[]) {

    int i, j, n, nn;
    int16 err;
    int8 start[4] = {0x02, 'M', 0x30, 0x31};
    int8 stop[4] = {0x02, 'M', 0x30, 0x30};
    int8 enter = 0x0D;
    int8 dat[256];

    if (argc > 1) USCM_ID = strtoul(argv[1], NULL, 16);
    if (argc > 2) JMDC_ID = strtoul(argv[2], NULL, 16);
    if (argc > 3) P = atoi(argv[3]);

    if (!initialize_EPP()) exit(1);

    boot_from_EEPROM(&err);
    for (i=0; i<3; i++) {
        ping(dat, &err);
        if (!err) break;
    }

    write_console(1, &enter, &err);

    write_serial_port(4, stop, &err);
    while (1) {
        read_serial_port(&n, dat, &err);
        if (n == 0) break;
    }

    write_serial_port(4, start, &err);
    usleep(10000);
    write_serial_port(4, stop, &err);

    nn = 0;
    for (i=0; i<256; i=i+n) {

```

```

    read_serial_port(&n, &dat[i], &err);
    if (n == 0) break;
    nn = nn + n;
}

for (i=0; i<nn; i++) {
    if (!(i % 7)) printf("\n");
    printf("%02X ", dat[i]);
}
printf("\n");

for (i=0; i<nn; i++) {
    if ((i % 7) == 0) printf("\n");
    if ((i % 7) == 0) printf("%02XH ", dat[i]);
    else                printf("%c ", dat[i]);
}
printf("\n");
}

//-----

```

References

- [1] A. Werner, "Box-C Electronics Test Plan," 13 May 2004.
- [2] <http://www.physik.rwth-aachen.de/group/IIIphys/Electronics/AMS-II/Software/Versions.htm>
- [3] B. Monreal, *Box C conductors and connectors*. Available: <http://web.mit.edu/awerner/www/BoxCPinout.pdf>, 18 Dec 2001.
- [4] ndd ASIC Specifications A1 - A4. ndd Medizintechnik AG, Zurich (2003)

Minutes of TRD Gas Electronics Meeting CERN, 11 August 2004

August 12, 2004

1 Note

In these notes, *italics* denote material that was discussed after this meeting. The meeting was called to discuss the results of the Level 1 tests performed on the TRD gas system electronics at CERN the week of 9 August 04. In attendance were A. Bartoloni, B. Borgia, J. Burger, M. Kamenetska, A. Lebedev, F. Spada, G. Rybka, and A. Werner.

2 Status of Box S

- All valves operated successfully—still need to reflect the fact that V5 doesn't exist.
- P1a/b, P2a. P2b was malfunctioning, but this was read correctly by the electronics hardware.
- Did corresponding temperature reads for the aforementioned sensors (same caveat for T2b).
- Need to read a Kulite sensor. Have given Kulite to Alessandro, (R. Becker has another one) and we need to see whether or not (preferably this week) it will work. A. Bartoloni says that sensor will not work in present configuration—needs rework.
- Simultaneous operation of V20a and V20b—successful!
- We need to decide whether we should prohibit simultaneous opening of V1a, V2a, etc., in hardware. During this test, we were able to open V1a and V2a via sequential commands.

3 Status of Box C

- All valves actuated successfully.

- All pressure sensors read successfully.
- Better voltage source for CP1/2 required.
- Current sense capability on pump? Is it necessary. *PF says not essential.*
- For spirometer, we need to understand how to put in a stable configuration.
 - A. Lebedev studies at CERN during this week.
 - Plans to improve buffering for greater reliability (HBB)
 - Alternatives to spirometer - Investigate.
 - Would like to have spirometer at CERN – ask PF. *Can use spirometer in EM Box C canister for development.*
- How to read from the MCA
 - New development at MIT/CERN for MCA
 - Need to make minimal changes to USCM in design process
 - Development coordinated at MIT. *Pending word from AMPTEK regarding software flow control in MCA8000A.*
- Dallas sensors on Box C.
 - Need series resistor onto Dallas bus.
 - Dallas connectors need to go on backplane
 - Need to talk to Sasha re: connection
 - How should Dallas sensors interface w/ UG crate?
 - * A. Lebedev suggestion: Do not use Y connector; use single connector and separate busses on backplane. So all Dallas direct to backplane?
- Serial port multiplexer function
 - Route both TTY circuits to USCM A+B on demand
 - Circuit to be developed on next version of UGBC
 - Need to discuss function with PF and UB. Do we use “I” or “X” redundancy?
 - With hot and cold circuits—need to ensure there is no hot-to-cold current leakage.
 - Do we need further tests with all redundant components in crate?
- Power supplies
 - GP:50 excitation of 10V—why are we using these? Are there other options? *Use 12V for GP:50 and calibrate at this voltage.*

- CO₂ sensor voltage of 8.5V.
- MCA sensor voltage — to be worked with and defined SOON by MIT.
- Switch power on/off via CANbus.

4 General UG-crate issues

- Shutoff in case of loss of communication to AMS? (B. Borgia)
- Why is this necessary? Only free-running piece of equipment is the Box-C circulation pump. (J. Burger)
- “Worst case” shutoff situation is leak in TRD causing loss of gas. No way to isolate manifolds in case of loss of communication. Should we have free-running program in computer? (JB)
- If we want to have a running program that autonomously flips the valve, where localized? Not in JMDC—we do not want to risk corrupting a high level program with additional complexity. (AL)
- The capability exists in UG-crate for a free-running program with some determination of thresholds. (AB)
- What are the possible emergency cases? What are characteristic times?
 - Possible 40 L/h loss with one broken straw tube.
 - Therefore possible loss of entire TRD volume on time scale of 6 hrs.
- Thus fast leak will be visible on the P3/P4 level. Emergency operational cases can be detected with UGBC FPGA.

5 Status of Manifolds

- After rewiring and concluding that AC/BD were flipped, all UGFV cards worked exactly as expected. All pressure sensors were read out where they were supposed to. It is thus outside the scope of Alessandro’s electronics.
- Pressure sensors gave readings of the correct measurements (1 mV/mbar).
- Open issue: Who makes cabling scheme?
 - Existing scheme incorporates Y-cabling scheme.
 - JB annotated his cabling scheme at the meeting.

6 Status of heaters

- Heaters go off of 120V and have own thermostats.
- U. Becker made fill tests and claimed that buffer volumes get cold during filling process. Heaters on valves should be combined at least with the smaller buffer volume. Would suggest that there should be some control other than thermostat control (i.e. only during filling.)
- 28V from power converters can go up to 5A, so can be used for heaters in principle provided that wattage is the same.
- What sorts of control do we have over 120V or 28V?
- 120V switching from PDS reduces reliability. (AL)
- So that leaves 28V, necessitating a new control circuit.
- Heating + control with 28V is complicated. Basic philosophy incorporates heating with the 120V PDS supplies.

7 Next steps

- AW + GR will measure flow rates of CP1 and CP2.
- Level 1 is finished.
- Do we do tests in Level 2? If so, which?
 - We have filling issues—need to open valve on S and valve on C simultaneously.
 - Should try test mix+fill.
 - Right now a Box C fill or a D vent requires simultaneous opening of valves on both C and S. This is not currently implemented.
 - For separate commands—what if one works correctly and another doesn't?

Reference [7]

August 2004 AMS-02 TRD Electronics Test

A. Bartoloni B. Borgia H.B. Broker J. Burger
M. Kamenetska A. Lebedev G. Rybka F. Spada
A. Werner

August 20, 2004

1 Introduction

During the week of August 9, 2004, we performed tests at CERN on the AMS-02 TRD Gas System Electronics with regard to its proper interaction with the S, C, and M subsystems. These tests included control of the valves and pumps and readout of the pressure, temperature, and CO_2 sensors from a USCM, as well as a gas mix, fill, and circulation simulation. Details of the test procedures can be found in the document "Preparation for Integrated TRD Gas System Electronics Test" by F. Spada and A. Werner.

2 Tests Performed

2.1 Level 1

- All of the installed valves on the engineering model of Box S and C and the sample manifold segments were operable from the electronics. Where no valve was installed on box S, control was confirmed by illumination of a LED. Valves tested are listed in table 1.
- Valves V20a and V20b were able to be simultaneously opened, and V1a and V2a were able to both be open at once using sequential CAN bus commands. Further simultaneous valve tests were postponed until what the proper behavior consists of is decided upon.
- The GP50 pressure sensors were successfully read out, as were the temperature sensors. Kulite sensors were not yet supported by the electronics and were thus not tested. Pressure and temperature sensors tested are listed in table 2.
- While the pump CP2 could be turned on to half speed, CP1 could not. It was discovered that CP1 drew more current than was anticipated, and because of this the electronics did not provide adequate voltage for the pump to turn on at half speed. Both pumps could be turned on to full

speed. The current draw of the two pumps measured while supplied from the manual control box is listed in table 3.

- The spirometer could be read from. However attempts to change the sampling rate would corrupt the data and require the spirometer to be power cycled in order to be read again.

2.2 Level 2

The electronics were capable of performing all of the actions required for a mix, fill, and circulation test, and the pressure sensors indicated gas was moving in the proper manner. However, due to leaks in the system and the temporary manner in which the gas systems were connected, the system could only be judged in a qualitative way. It could not be brought up to full pressure, and fill times could not be measured.

3 Decisions Made During the Course of the Test

- The GP50 excitation voltage on Box C was chosen to be 12 volts, which is currently supplied from the UGBC
- A. Bartoloni will have a Kulite sensor to use for development of differential ADC inputs for the UGBS.
- The pump power supply will be reworked to continue to function for variable current draw.
- Labeling of pressure sensors will be made to match the diagram by J. Burger.
- The functionality to turn power to the MCA and spirometer on and off by CANbus command will be added.
- A. Bartoloni will investigate the feasibility of multiplexing the Box C serial ports for redundancy.

4 Remaining Open Issues

- Which valves are allowed to be open at the same time needs to be decided upon. If valves are prohibited from opening together, it needs to be decided whether they will be prohibited by the software or hardware. Additionally, for valves that must be opened simultaneously, we need to decide if the addition of CANbus commands that open both valves at once is necessary.
- The malfunction of the spirometer when given the command to change its rate needs to be investigated.

- How the Dallas temperature sensors connect to the USCM, and where the limiting resistor for them is placed needs to be decided.
- The MCA communication and power requirements need to be decided upon and incorporated into Box C and the electronics.
- A cabling scheme between the manifolds and the electronics needs to be decided upon.
- Configuration and power requirements of heaters in box S need to be discussed.
- In the event of power or communication loss to AMS, the behavior of the valves should be specified. It needs to be discussed that if a large leak occurs during a period of communication loss, what actions the slow control will take autonomously.
- The connector type for JC3 between Box C and UGBC needs to be decided upon.

| Box S Valves Tested | | Box C Valves Tested | |
|---------------------|------|---------------------|------|
| V1A | V1B | V6A | V6B |
| V10A | V10B | V18A | V18B |
| V2A | V2B | V8A | V8B |
| V3A | V3B | | |
| V4A | V4B | | |
| V20A | V20B | | |

Table 1: Valves tested. One manifold segment worth of valves were also tested successfully.

| Box S Sensors Tested | | Box C Sensors Tested | |
|----------------------|-----|----------------------|----|
| P1A | P1B | P3 | P4 |
| P1A | P1B | P3 | P4 |
| P2A | P2B | T3 | T4 |
| T1A | T1B | | |
| T2A | T2B | | |

Table 2: Pressure and Temperature Sensors tested. The six pressure sensors along one manifold segment were also tested successfully.

| Pump | Setting | Current w/ V8 closed | Current w/ V8 open |
|------|---------|----------------------|--------------------|
| CP1 | high | 0.32 A | 0.40 A |
| | low | 0.24 A | 0.32 A |
| CP2 | high | 0.14 A | 0.17 A |
| | low | 0.10 A | 0.12 A |

Table 3: CP1 and CP2 current draw

Integrated test of the TRD Gas System electronics

A. Bartoloni, B. Borgia, F. Bucci, F.R. Spada*

Dipartimento di Fisica, University of Rome “La Sapienza”
and INFN Sezione di Roma
Piazzale Aldo Moro, 2 – I-00185, Rome, Italy

March 6, 2006

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1 Introduction

The test performed in August 2004 [1] at CERN on an integrated gas system apparatus was meant to demonstrate the capability of the control electronics to operate on a gas system in a configuration as close as possible to the final one. For the first time the complete *hot* component of the electronics was successfully operated simultaneously – tests performed in previous times (december '03 [2], march '04 [3] and may '04 [4] all concerned a subset of the gas system, and consequently a subset of the control electronics.

The WINCAN control software used in the tests consists of a series of graphical user interfaces that allow the communication with the gas system via the control electronics.

*francesca.spada@Roma1.infn.it

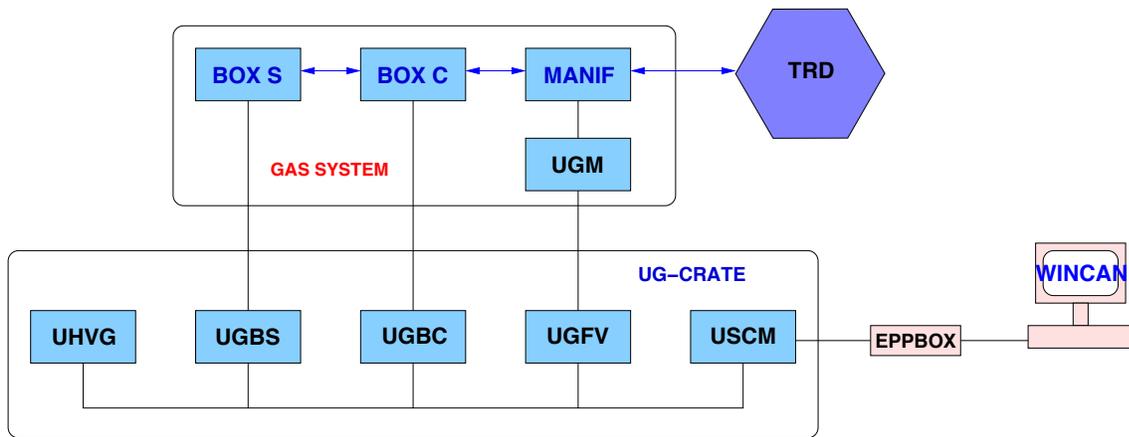


Figure 1: Slow control scheme.

Each button push corresponds to a LeCroy protocol command or a serial port address, issued via the CAN bus through the AMS EPP box (see figure 1).

This document is an update of the status of the TRD gas system slow control electronics. In December 2005 a test on the engineering version of the gas system, temporarily in Rome, was performed on a set of slow control electronics including both a *hot* and a *cold* USCM. Subsequently in February 2006 the control electronics, equipped with *hot* and *cold* modules, was operated successfully.

2 The control software

The controllers for box S, box C and for *all* the manifold segments are shown in figures 3, 2 and 4. For a more complete description, see ref. [5].

An example of more complex procedure is given by the gas mixing procedure utility shown in figure 5. For more details on the operations that the software allowed to perform during the CERN tests, see section 3.

3 Reminder: the August '04 tests

3.1 Test setup

The apparatus consisted of box S, box C plus 1 manifold segment. The mechanical components consisted of:

- box S:
 - Marotta MV197 valves V1a, V2a, V3a, V4a, V10a, V20a, V1b, V2b, V3b, V4b, V10a, V20a;
 - GP50 7900 pressure sensors P1a, P1b, P2a, P2b (also temperature sensors);
- box C:
 - Marotta MV100 valves V6a, V18a, V6b, V18b;
 - Bürkert 6124 *flipper* valves V8a and V8b;
 - GP50 7900 pressure sensors P3 and P4 (also temperature sensors);

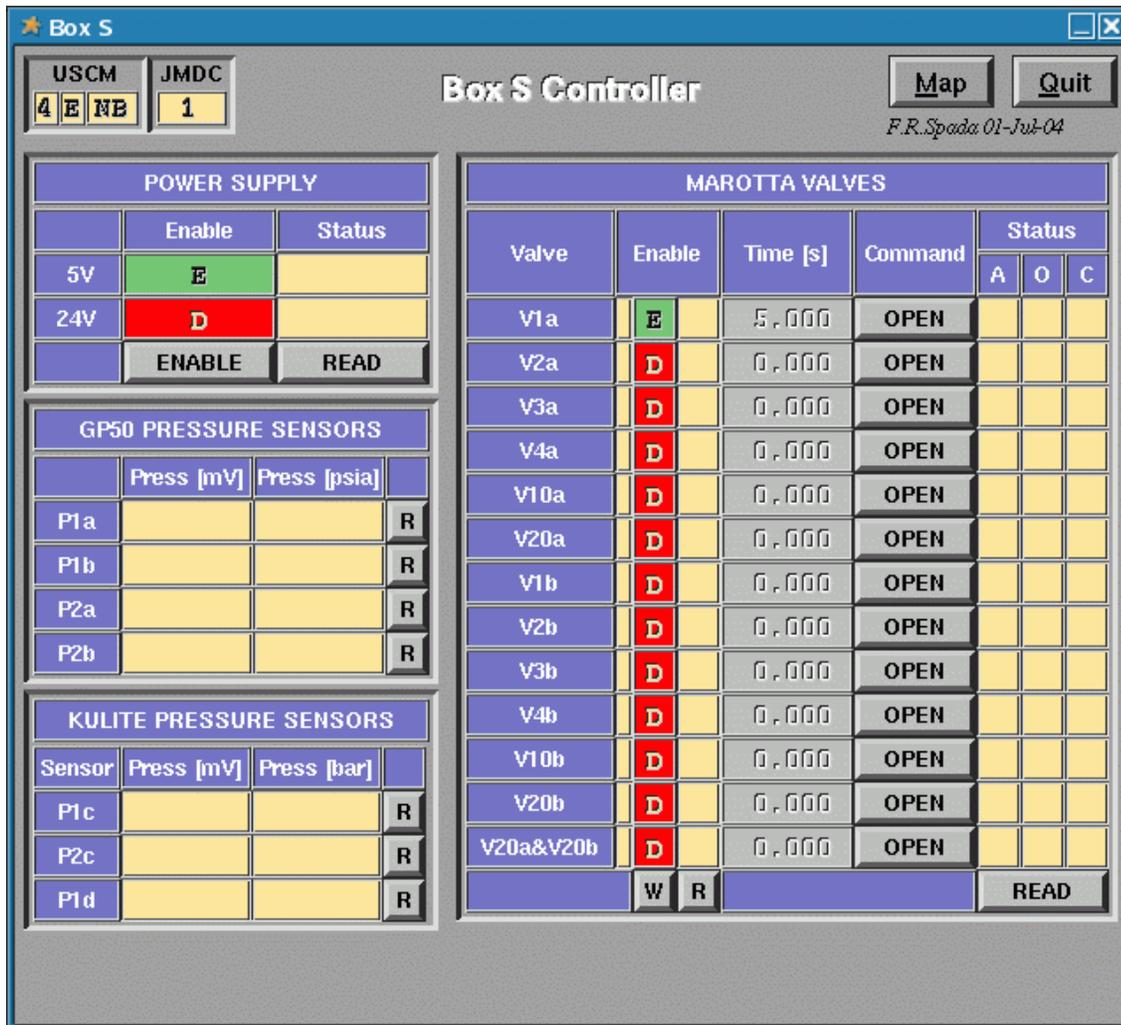


Figure 2: The WINCAN box S control interface.

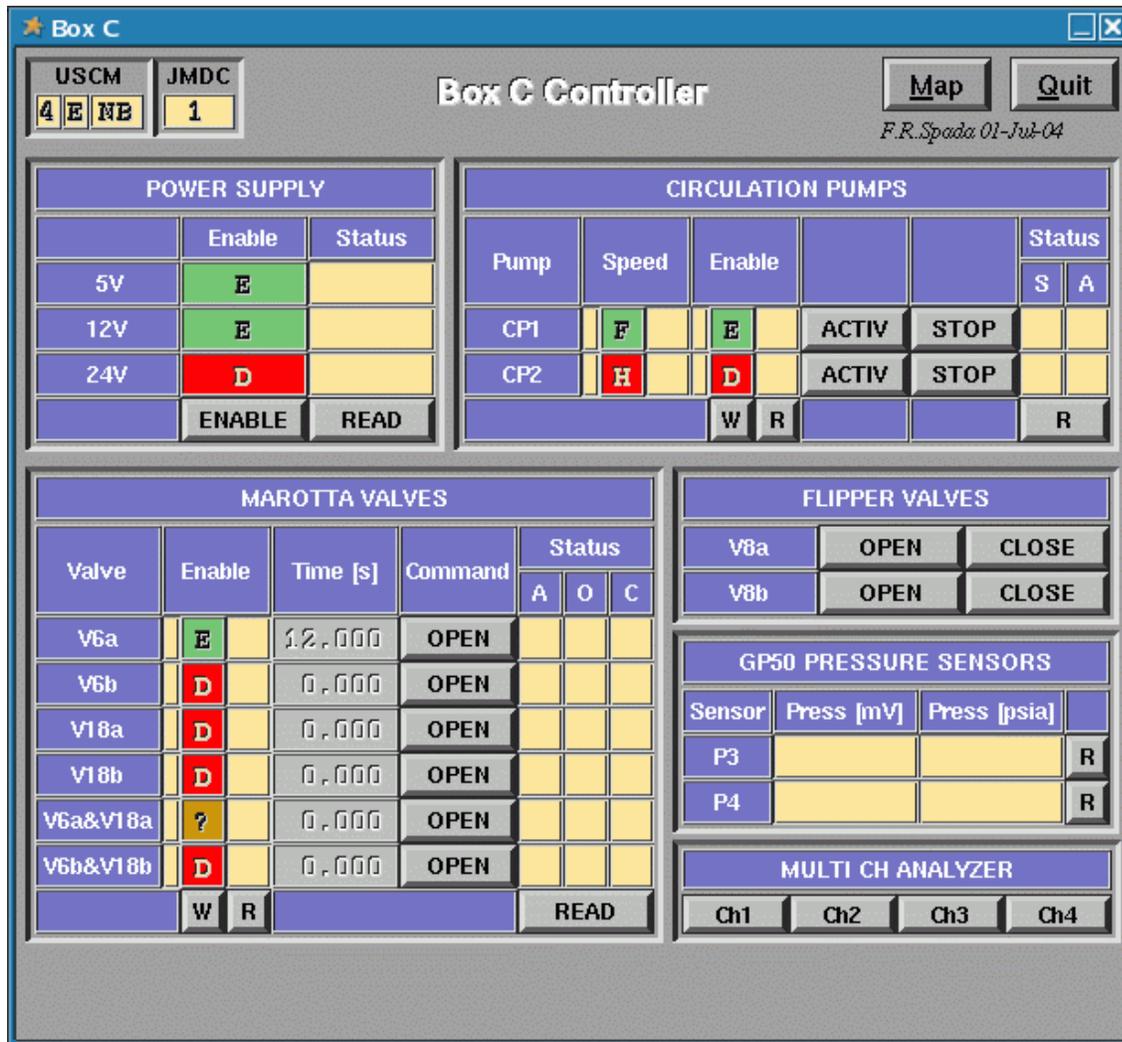


Figure 3: The WINCAN box C control interface.

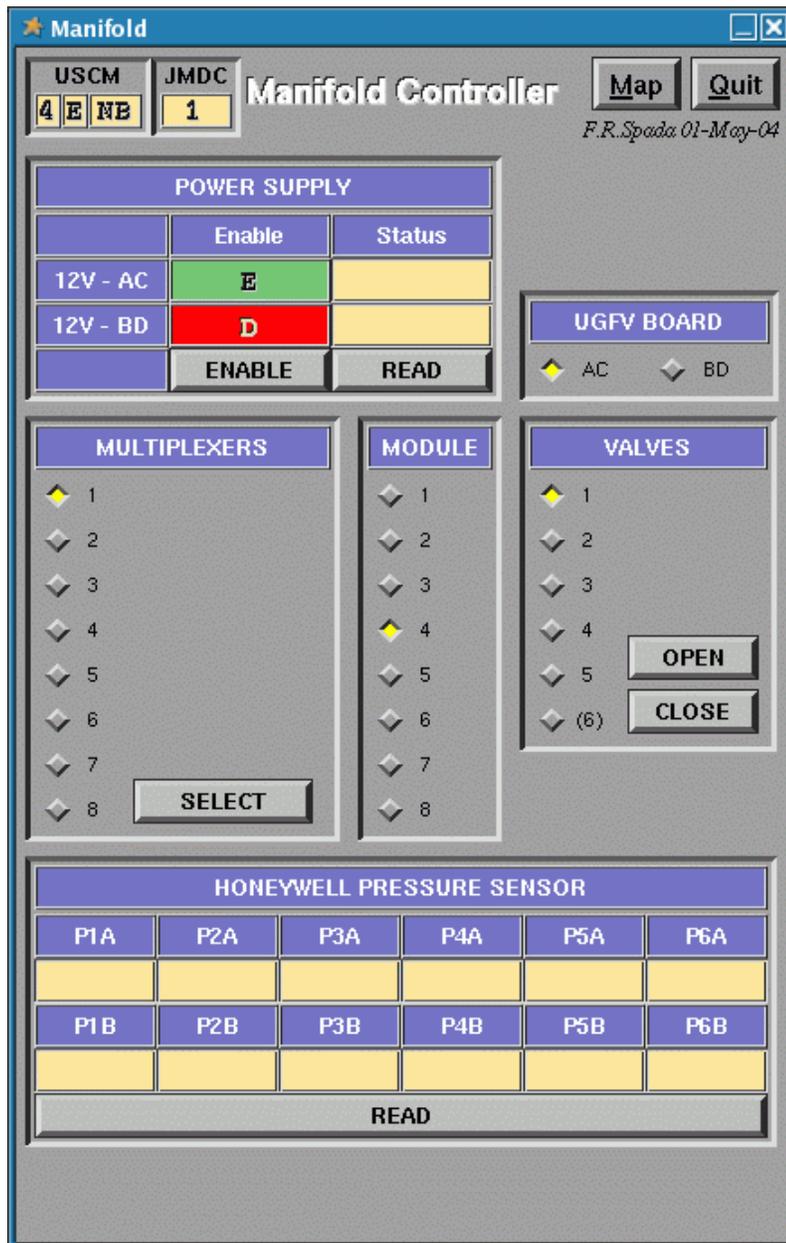


Figure 4: The WINCAN control interface for manifold segments.

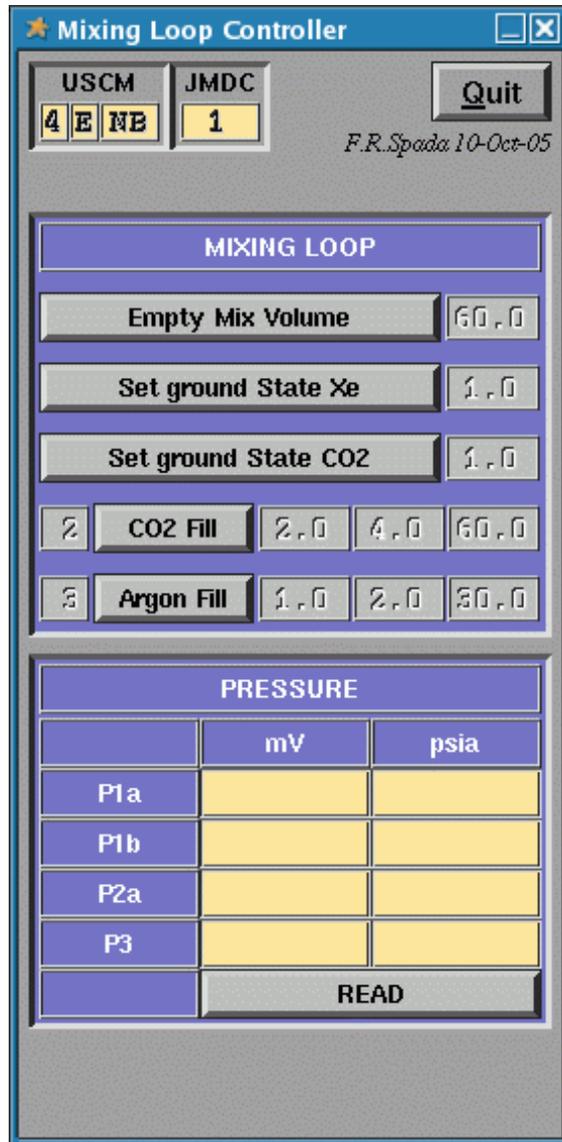


Figure 5: The WINCAN interface to control the mixing procedure.

- KNF UMNP830 circulation pumps CP1 and CP2;
- ndd ASIC spirometer;
- one manifold segment:
 - Bürkert 6124 *flipper* valves Va, Vb, Vc and Vd;
 - Honeywell 26PCCFA6D pressure sensors Pa and Pb.

See also table 1 for a list of the full test equipment.

Electronic components under test consisted of the hot USCM, UGBS, UGBC, and the two UGFV boards connected through the UG-crate backplane and controlled by a computer interface. The electronics was totally controlled via a software user interface (called *WINCAN* [5]) including a box S controller, a box C controller, a manifold controller and few other programs where sequences of higher level commands, e.g. the mixing procedure, were hard-coded. The computer control was operated by an ACER laptop with Linux Red Hat 9b and the *WINCAN* software (see section 2) installed, that was connected to the CAN bus via the AMS EPPBOX (see figure 1).

3.2 Low level tests

This part of the test was meant to confirm that the electronics can successfully control all the electromechanical components individually.

- All the valves were successfully operated;
- A command to simultaneously open valves V6a and V18a, as well as V6b and V18b is foreseen in the electronics and was successfully issued and executed. In addition, it was confirmed that it is possible to keep two valves open simultaneously – e.g. V1a and V2a – using sequential CAN bus commands to open them;
- The GP50 pressure sensors were successfully read out, as well as the temperature sensors;
- While the pump CP2 were turned on to half speed, CP1 could not. It was discovered that CP1 drew more current than was anticipated, and because of this the electronics did not provide adequate voltage for the pump to turn on at half speed. Both pumps were turned on to full speed.
- The spirometer was read out correctly. However attempts to change the sampling rate would corrupt the data and required the spirometer to be power cycled in order to be read again.

3.3 Higher level tests

The electronics was capable of performing all the required higher level actions (see below). However, due to leaks in the system, the behaviour of the system as a whole could only be observed in a qualitative way.

3.3.1 Mixing procedure

This sequence of operations was meant to fill up the mixing vessel with the Argon/CO₂ gas mixture and consisted of the following steps (these step names correspond to the operations on mechanical components described in table 2):

| | |
|---------------------|--|
| Power supply | 24 V 12 V 5 V |
| Electronics | UG-crate USCM UGBC UGBS UGFV x2 |
| Marotta MV197 | V1a V2a V3a V4a V10a V20a V1b V2b V3b V4b V10b V20b |
| Marotta MV100 | V6a V18a V6b V18b |
| Bürkert 6124 | V8a V8b Vma Vmb VmC VmD |
| gp50 7900 | P1a P1b P2a P2b P3 P4 |
| Honeywell 26PCCFA6D | Pma Pmb |
| KNF UMNP830 | CP1 CP2 |
| nnd ASIC spirometer | |

Table 1: The gas system components tested in the August '04 test at CERN.

1. Empty mix volume (open D vessel to external atmosphere)
2. Set to ground state Xe (open intermediate buffers on Xenon line to external atmosphere)
3. Set to ground state CO₂ (open intermediate buffers on CO₂ line to external atmosphere)
4. Empty mix volume
5. CO₂ fill step
6. Xenon fill step
7. Xenon fill step
8. Xenon fill step
9. Empty mix volume
10. Empty mix volume
11. Empty mix volume
12. Empty mix volume
13. Empty mix volume

| | |
|-------------------------------------|---|
| Empty mix volume | Open V4a, V6a, and V18a for 60 s, wait 10 s |
| Set to ground state Xe | Open V2a for 1 s, wait 5 s, open V3a for 1 s, wait 5 s, open V4a and V18a for 60 s, wait 10 s |
| Set to ground state CO ₂ | Open V2b for 1 s, wait 5 s, open V3b for 1 s, wait 5 s, open V4a and V18a for 60 s, wait 10 s |
| CO ₂ fill step | Open V1b for 1 s, wait 5 s, open V2b for 1 s, wait 5 s, open V3b for 40, wait 10 s |
| Xenon fill step | Open V1a for 1 s, wait 5 s, open V2a for 1 s, wait 5 s, open V3a for 40, wait 10 s |

Table 2: Definition of the mixing procedure steps.

3.3.2 Filling procedure

The following sequence filled the manifold segment including the volume that was simulating one fourth of the TRD volume (see table 3 for the action definitions):

1. Close valves of Box C
2. Stop pumps
3. Open manifold segment
4. Connect Box S to Box C
5. Check pressure

| | |
|------------------------|--|
| Close valves of Box C | Close V8a, V8b, V6a, V6b, V18a, V18b |
| Stop pumps | Turn off CP1 and CP2 |
| Open manifold segment | Open Va, Vb, Vc and Vd |
| Connect Box S to Box C | Open V4a and V6a for 5 s |
| Check pressure | Check if P4 is in nominal range of 17-25 psi. If not, repeat 4-5 |

Table 3: Definition of the filling procedure steps.

3.3.3 Circulation

This procedure circulates the gas mixture in the manifold segment (see table 4 for action definitions):

1. Choose circuit
2. Turn pump to High Speed
3. Turn pump to Low Speed

| | |
|-------------------------|---|
| Choose circuit | Open V8a or V8b according to the chosen pump |
| Turn pump to High Speed | Turn CP1(CP2) to high speed and wait for a given P4 |
| Turn pump to Low Speed | Turn CP1(CP2) to low speed, keep recording P4 |

Table 4: Definition of the circulation procedure steps.

Even though the electronic and the control software were successfully operated on the system and the correct actions were executed, a leakage in the gas pipes prevented the TRD volume to be filled, so that the regime situation was never reached and the fill time could not be measured.

4 Update: the Hot/Cold electronics tests

A slow control electronic set composed of two USCMs, one UGBS (hot) and one UGBC (hot) was tested in december 2005 on an engineering model of the gas system box S and box C currently available in the Rome INFN clean room. The scheme of the gas circuit is shown in figure 6. The aim of the test was to exclude that some conflict could arise in the joint use of two USCM modules. One UGSCM (identification number 0xA0 newborn) was used as *hot* and a second USCM (0x4E newborn) as *cold*. The 0xA0 is of new type with Dallas patch panel, while the 0x4E is of old type (no Dallas patch panel, no Dallas connectors). A third USCM (the 0x97 newborn, new type but no Dallas patch panel) has also been tested alternatively with the other two.

No conflict in the electronics was observed. All the components responded correctly, no matter which USCM (*hot* or *cold*) was addressed. The success of the communication with the serial ports was confirmed by the fact that the two devices connected answered correctly, and the data was transmitted in the format expected.

In February 2006 further tests were carried out, on a set of hot and cold USCM, UGBS and UGBC. These tests are described in detail in the following sections.

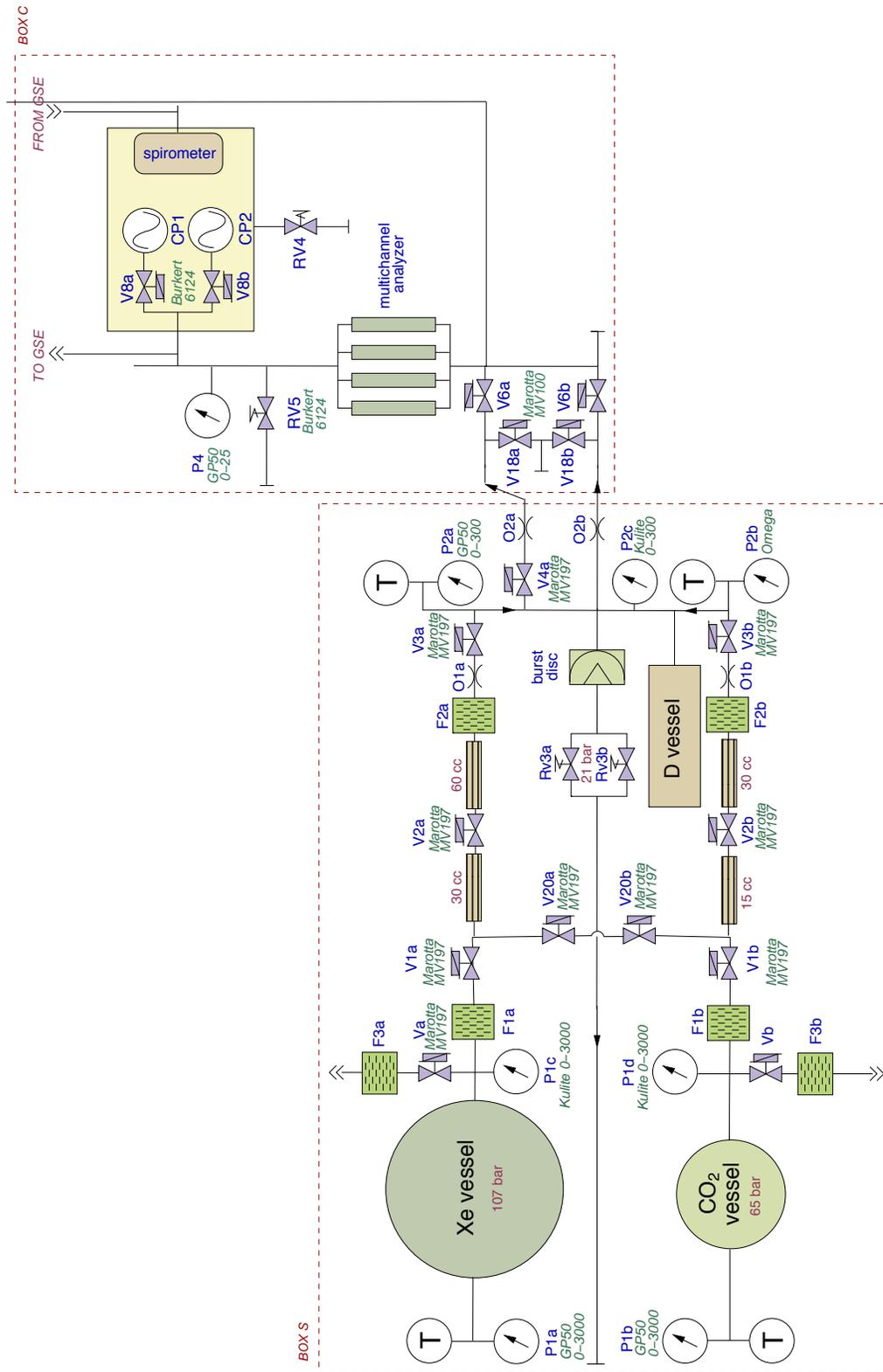


Figure 6: Layout of the gas system used in the test.

4.1 Test setup

The mechanical components available in the engineering model of the gas system box S and box C are listed in table 5. The V10a and V10b valves were substituted by leds, and the corresponding open command addressed the two tanks heaters instead. The valve V4b was not present, and was substituted by a led. The CO₂ analyzer and the MCa were connected to the USCM RS232 serial ports through the UGBC serial ports, so that they could be addressed from both the USCMs.

4.2 Hot/Cold USCM interaction test

The following operations were successfully executed with the control software described in section 2.

- UGBS-controlled operations:
 - open valves V1a, V2a, V3a, V4a, V20a, V1b, V2b, V3b, V4b, V20b
 - read pressure sensors P1a, P1b, P2a, P2b
 - activate CO₂ and Xenon tanks heaters
- UGBC-controlled operations:
 - open valves V6a, V6b, V18a, V18b
 - read pressure sensor P4
 - open and close V8a and V8b
 - activate pumps CP1 and CP2 at half and full speed
 - communicate with the RS232 serial port

All the above operations were repeated four times, in all the possible hot/cold combinations: addressing the *hot* USCM and alternatively the *hot* UGBS/UGBC and the *cold* UGBS/UGBC, then again through the *cold* USCM.

One can tell the correct functioning of the Marotta valves either by the valve click, or looking at the leds connected to the valves, and finally from the increase in the absorbed current (about 700 mA). For the flipper valves only the click shows the execution of the command. The pumps can be checked both by their humming and by the current absorption (about 400 mA at half speed, 550 mA at full speed).

No conflict in the electronics was observed. Except sensor P4 (broken) and valve V8b (no click), featuring known hardware problems, all the components responded correctly, no matter which boards was addressed. The results of the tests are summarized in table 6.

5 Conclusions

The tests carried out from 2003 to 2006 showed that the engineering model of the gas system slow control electronics works correctly and can perform the required operations.

References

- [1] A. Bartoloni, B. Borgia, H.B. Broker, J. Burger, M. Kamenetska, A. Lebedev, G. Rybka, F.R. Spada, A. Werner, “August 2004 AMS-02 TRD Electronics Test” (internal note, 2005)

| | | |
|----------------|--|--|
| Power supply: | 24 V 12 V 5 V | |
| Electronics: | UG-crate USCM <i>hot</i> USCM <i>cold</i> UGBC UGBS | |
| | Box S | Box C |
| Marotta MV197: | V1a V2a V3a V4a V20a V1b V2b V3b V4b (led) V20b | |
| Marotta MV100: | | V6a V18a V6b V18b |
| Bürkert 6124: | | V8a V8b |
| gp50 7900: | P1a P1b P2a | P4 |
| Omega: | P2b | |
| KNF UMNP830: | | CP1 CP2 |
| | CO ₂ heater Xe heater | |
| | | ndd ASIC spirometer Amptek MCA8000A |

Table 5: The gas system components tested in the Hot/Cold test in Rome.

| | USCM HOT | | USCM COLD | |
|--------------------|----------|-----------|-----------|-----------|
| | UGBS HOT | UGBS COLD | UGBS HOT | UGBS COLD |
| enable 5 V | ok | ok | ok | ok |
| enable 24 V | ok | ok | ok | ok |
| open V1a | click | click | click | click |
| open V2a | click | click | click | click |
| open V3a | click | click | click | click |
| open V4a | click | click | click | click |
| open V10a | led on | led on | led on | led on |
| open V20a | click | click | click | click |
| open V1b | click | click | click | click |
| open V2b | click | click | click | click |
| open V3b | click | click | click | click |
| open V4b | led on | led on | led on | led on |
| open V10b | led on | led on | led on | led on |
| open V20b | click | click | click | click |
| open V20a & V20b | click | click | click | click |
| read P1a | ok | ok | ok | ok |
| read P1b | ok | ok | ok | ok |
| read P2a | ok | ok | ok | ok |
| read P2b | ok | ok | ok | ok |
| | UGBC HOT | UGBC COLD | UGBC HOT | UGBC COLD |
| enable 5 V | ok | ok | ok | ok |
| enable 12 V | ok | ok | ok | ok |
| enable 24 V | ok | ok | ok | ok |
| open V6a | click | click | click | click |
| open V18a | click | click | click | click |
| open V6b | click | click | click | click |
| open V18b | click | click | click | click |
| open V6a & V18a | click | click | click | click |
| open V6b & V18b | click | click | click | click |
| open V8a | click | click | click | click |
| close V8a | click | click | click | click |
| open V8b | ? | ? | ? | ? |
| close V8b | ? | ? | ? | ? |
| read P4 | ? | ? | ? | ? |
| run CP1 half speed | ok | ok | ok | ok |
| run CP1 full speed | ok | ok | ok | ok |
| run CP2 half speed | ok | ok | ok | ok |
| run CP2 full speed | ok | ok | ok | ok |

Table 6: Summary of the Hot/Cold test done in Rome (february '06).

- [2] A. Bartoloni, C. Bosio, J. Burger, S. Gentile, “*AMS-02 TRD gas system manifold electronics test*” (internal note, 2004)
- [3] A. Bartoloni, C. Bosio, J. Burger, S. Gentile, F.R. Spada, “*AMS-02 TRD UGBS electronics test on engineering Box S*” (internal note, 2004)
- [4] A. Bartoloni, C. Bosio, J. Burger, S. Gentile, F.R. Spada, A. Werner, “*AMS-02 TRD UGBC electronics test on engineering Box C*” (internal note, 2004)
- [5] F. Bucci, S. Gentile, A. Lebedev, F.R. Spada, “*WINCAN v.2.2 – Slow Control commands and operations for the TRD gas system of AMS-02*” (internal note, 2006)

Readout of the Multi Channel Analyzer and test of the monitor tubes

F.Bucci, F.R.Spada

10/2/2006

The tests described here show that we can successfully read out the multi-channel analyzer. This is confirmed by the fact that the spectra obtained from the monitor tubes, and the behaviour of the peak with the voltage applied, are as expected.

The readout of the MCA was performed with the corresponding user interface included in the WINCAN software¹.

In order to study the response of the MCA to the input voltage, we first sent input signals to the MCA from a pulse generator with the following features:

- amplitudes in the range 50 mV – 4.5 V;
- width = 1 μ s;
- frequency = 10 kHz;
- edge time = 100 ns.

Data were taken in a period of 30 s, and the spectra from the MCA were recorded for each input amplitude. The spectra actually consisted in a sharp peak corresponding to a single ADC bin. This provides a calibration of the response of the MCA to the input amplitudes. The result is shown in figure 1. No counts have been observed in the MCA under 200 mV, due to an intrinsic threshold of the instrument. Then a linear rise follows up to about 2 V, followed by a saturation up to the maximum amplitude applied².

We then tested the monitor tubes flushing into them an Ar/CO₂ (80:20) premixed mixture. The HV was provided by the UHVG board, and the

¹F. Bucci, S. Gentile, A. Lebedev, F.R. Spada, “WINCAN v.2.2 - a Linux-based Slow Control interface for the AMS TRD Gas System”, AMS internal note.

²A modification of the Kang Lee board to be introduced in the next version should allow to cure this problem.

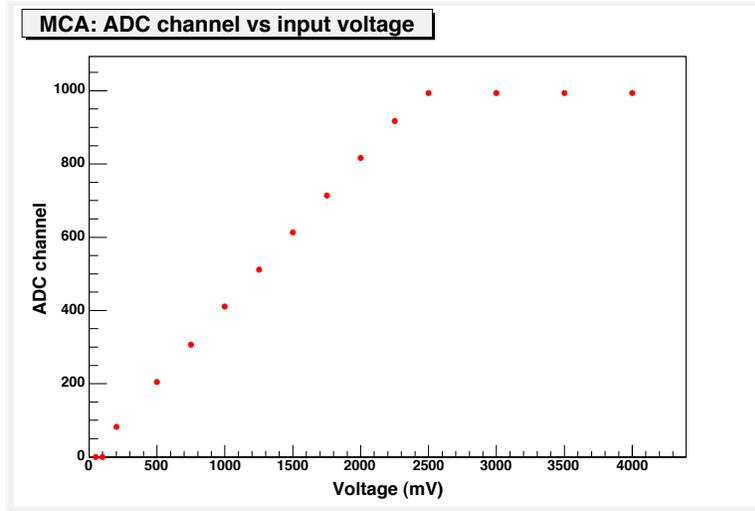


Figure 1: MCA calibration with signals from a pulse generator.

readout was performed using the MCA on the first channel of the amplifier. The measurements were taken setting the acquisition time of 30 s, for different values of HV applied to the tubes.

Figure 2 shows the trend of the number of counts as a function of the HV applied to the tubes. We observe noise below 1000 V, then a proportional rise up to 1150 V, while the plateau region is found around 1250 V.

Two typical spectra of the ^{55}Fe source, namely the ones obtained at an applied voltage of 1325 V and 1350 V, are given in figure 3. The escape peaks clearly show up at half the photopeak value. For the first plot we see that the main peak is found (subtracting the pedestal) at $253.9 - 50.0 = 203.9 \pm 3.5$, while the secondary peak is at $156 - 50 = 106 \pm 11$, the ratio being 0.52 ± 0.05 . For the second plot, as well, we get a main peak at $329.6 - 50.0 = 279.6 \pm 4.6$ and a secondary peak at $198 - 50 = 148 \pm 12$, giving a ratio of 0.53 ± 0.04 .

Figure 4 shows the mean ADC channel from the MCA spectrum as a function of the high voltage applied to the tubes. As expected, the curve rises with increasing voltage.

We conclude that the electronics correctly deals with the multi channel analyzer, and the readout shows results in agreement with the trends expected.

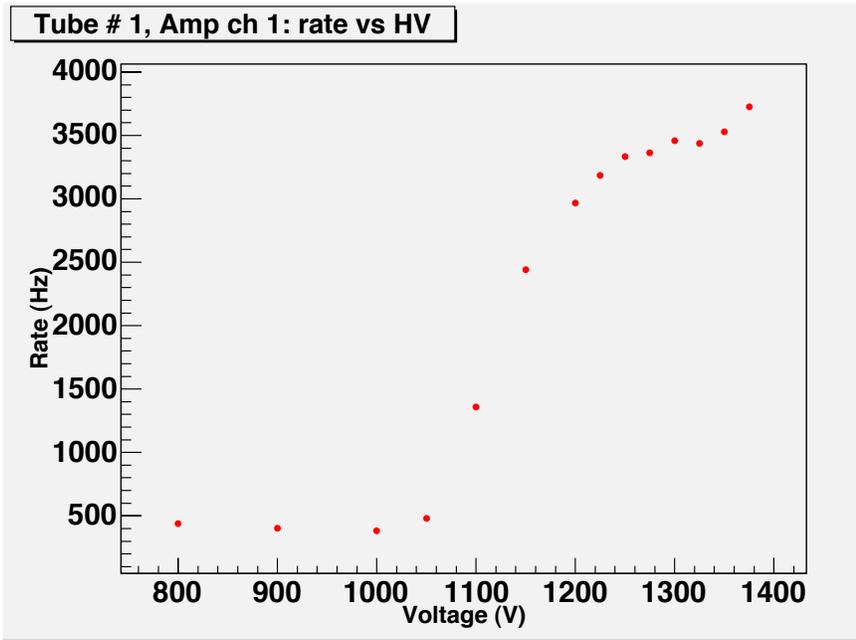
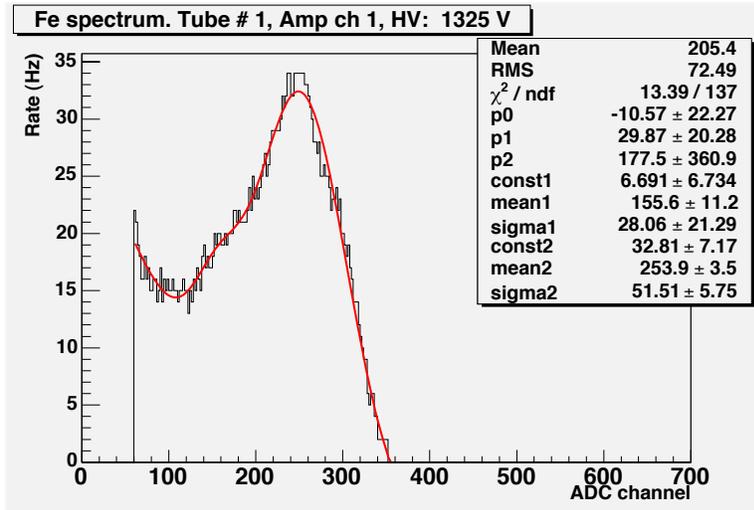
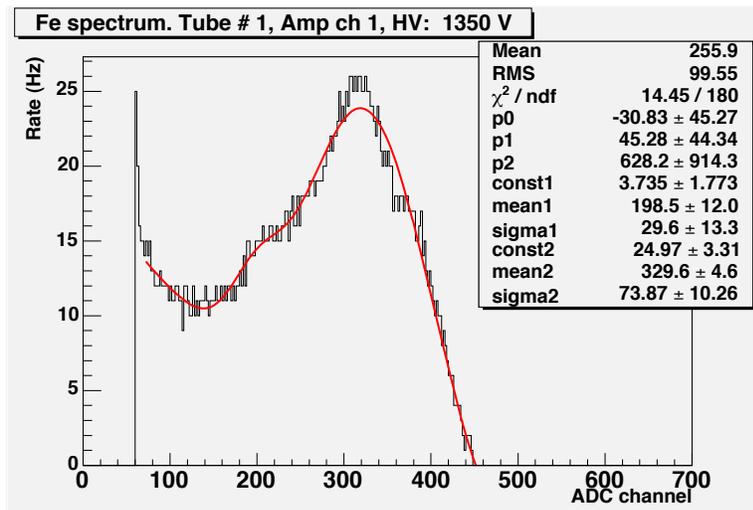


Figure 2: Number of counts from the MCA as a function of the high voltage applied to the monitor tubes.



(a)



(b)

Figure 3: ^{55}Fe spectrum recorded at 1325 V (a) and 1350 V (b).

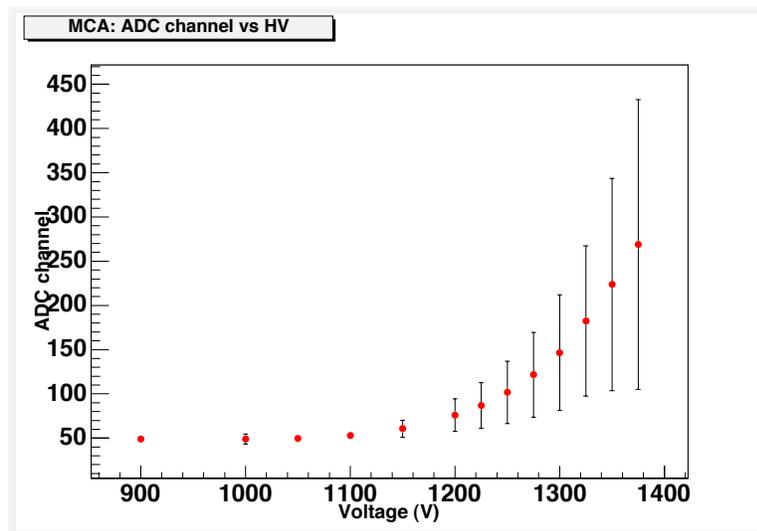


Figure 4: Mean ADC channel from the MCA response as a function of the high voltage applied to the tubes.

Calibration of Dallas sensors

Mariusz Sapinski

INFN Sezione di Roma1 – Roma, Italy

(April 2006)

1. Objectives

The goal of this work is to perform a calibration of Dallas sensors.

Nine Dallas sensors are glued in different places of the mechanical structure of the engineering model of the box S of the gas system of the AMS Transition Radiation Detector. These sensors provide temperature measurement with an accuracy of about 0.5 °C [1]. They are glued to the structure with epoxy glue of unknown thermal conductivity. In our tests they were read out by USCM (300/S2 #078, ID 4E). The data taking were realized with WINCAN Dallas Sensor Commander program [2]. The tests lasted between 6 and 12 hours, no malfunctions were observed during these periods.

The thermometers used to perform calibration of Dallas sensors are platinum thermometers. They provide accuracy of 0.01 °C. Their readout is via RP7000 temperature analyzer¹ connected via GBIP to a PC with LabView. These thermometers were glued with use of black electrical scotch tape, as close to Dallas sensors as possible. Nevertheless the distance between platinum thermometer and Dallas sensor were usually about 0.5 cm, what is a source of a systematic error discussed later.

The whole setup is placed in laboratory with air-conditioning and cannot be moved to another place, what means that a local heaters must be used to perform the calibration. The air-conditioning cannot be regulated. It keeps the room temperature of about 21 °C and it has a characteristic working cycle of about 50 minutes. The amplitude of temperature changes during the cycle, measured by platinum thermometers is about 0.2 °C. Additional, smaller temperature variations appear with a period of 24 h.

In such conditions, even if the frame of the setup is made of thermally well conductive aluminum, the heat distribution leads to temperature gradients, which can be only roughly estimated.

The calibration strategy is to take the measurements in at least two temperature points and fit a straight line:

$$T_{\text{Dallas}} = p_1 T_{\text{Pt}} + p_0$$

¹ See: <http://www.francocorradi.it/strumentiMisuraTemperatura.htm>

For every temperature point, in order to minimize the influence of temperature fluctuations, an average over many measurements is taken.

The error of the Dallas sensor measurement is simply equal to accuracy i.e. 0.5 °C. The error of the platinum thermometer measurement is estimated as a standard deviation of the chosen set of measurements.

2. Sensors close to Xenon and CO₂ bottles

The grip handles of the CO₂ and Xe bottles are equipped with build-in heaters. These heaters have power of about 10 W and are build-in into aluminum block. Their location provide good heat dispersion. They are able to heat-up the block by about 10 °C. The unique sensor addresses are: 10F6528E00080097 (CO₂ bottle) and 10B45B8E0008007F (Xe bottle). The typical heating process for sensor 10F6528E00080097 is shown in Figure 1.

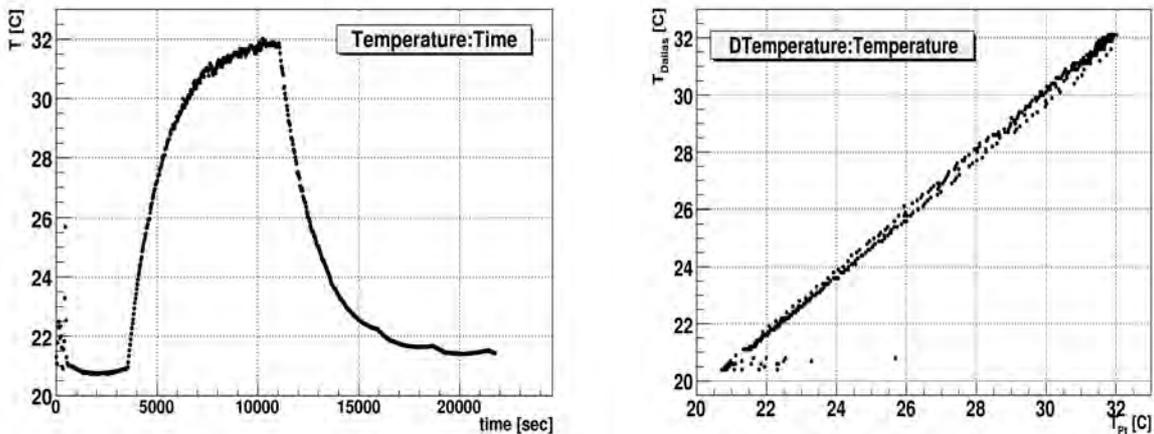


Figure 1: Left plot: example of heating cycle for Pt thermometer placed near Dallas sensor 10F6528E00080097. Right plot: hysteresis for the same sample.

This heating is performed using 250 heating cycles of 30 s each with duty factor of 70%. The readout was performed every 30 s. The initial heating rate is about 0.18 °C/min. The resulting temperature difference between cold and hot point is about 10 centigrades. In Figure 2 the determination of the calibration parameters with a linear fit is presented.

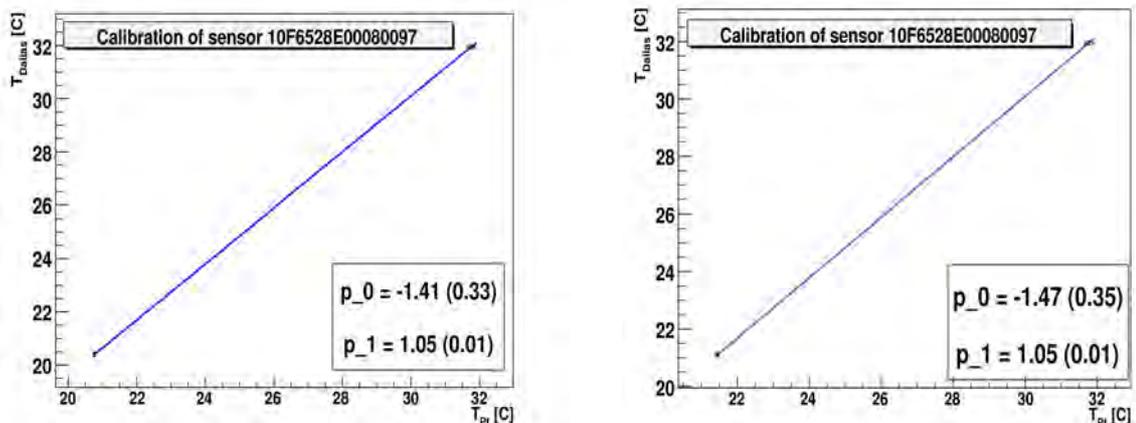


Figure 2: Calibration of the sensor 10F6528E00080097 during heating (left plot) and during cooling down (right plot).

The results during heating and during cooling down are compatible within errors. As the final result the one with smaller statistical errors has been chosen.

3. Sensor on the mixing vessel

The mixing vessel is made of thin steel so it behaves thermally in a different way than other parts of the gas mechanical structure which are made of aluminum.

There are no internal build-in heaters on the mixing vessel so an external heater was placed on the vessel in the neighborhood of platinum thermometer and Dallas sensor (approximately in the same distance from both of them). The heater was an electric resistance heater of with power of 4 W. An example of a heating curve for this sensor is shown in Figure 3.

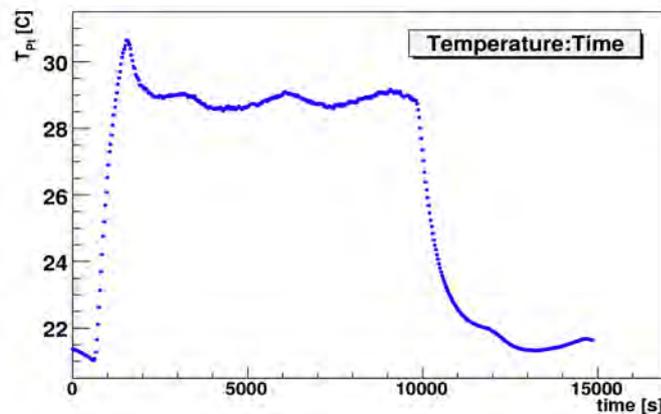


Figure 3. Heating curve for the sensor on the mixing vessel (106F4A8E000800F2). The initial peak is due to over heating and it was excluded from the analysis.

With respect to heating curve of the sensors close to build-in heaters we notice that the heating is much faster ($0.5\text{ }^{\circ}\text{C}/\text{min}$). Another difference is a visible influence of the air-conditioning on the temperature measurements from the Pt thermometer. This is probably due to lower power of the heater.

4. Sensors on the aluminum structure

Finally a calibration for two Dallas sensors glued to flat parts of the aluminum structure has been performed. The aluminum structure is large and thin so the heat dissipation is much stronger than in case of previous measurements. This is a reason of larger errors for these measurements. The temperature difference between the cold and warm calibration point is of the order of only 4 centigrades. An example of the heating cycle for one of the sensors is shown in Figure 4.

The periodic behavior due to air-conditioning is visible. Averaging over a few periods were done in order to avoid systematic error.

The four sensors which have not been calibrated are glued in places where it was not possible to put platinum thermometers close to the sensors. The accuracy of the calibration of these sensors would suffer from very large and difficult to estimate systematic error.

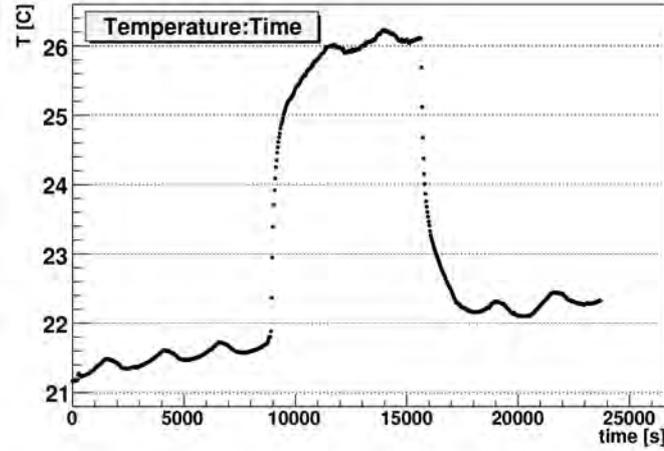


Figure 4: Example of a heating curve for the sensor 10A64A8E000800FB.

5. Results

The results of the calibration are presented in Table 1. In the second column the calibration constant (p_0) is shown and in the third one the calibration coefficient (p_1). The errors presented there are statistical, obtained from linear regression.

Additional systematical error should be added to p_0 parameter due to the heat flow. This error has been estimated using the approximative values.

Assume that the aluminum frame temperature is T_0 . The temperature of the Dallas sensor is expressed:

$$T_{\text{Dallas}} = T_0 - (Q \cdot d / A \cdot \lambda)$$

where: Q – heat flow, d – distance between heater and Dallas sensor, A – surface of the contact between sensor and the mechanical structure, λ – thermal conductivity of the contact between sensor and surface.

A similar statement can be written for platinum thermometer, but as platinum thermometers are pressed to the surface without any glue it is a good approximation to assume that the thermal conductivity for platinum thermometers is much larger than in case of Dallas sensors ($T_{\text{pt}}=T_0$).

For typical values : $Q = 1 \text{ W}$, $d = 5 \text{ mm}$, $A = 0.1 \text{ cm}^2$, $\lambda = 10 \text{ (W/m}\cdot\text{K)}$

$$T_{\text{Dallas}} - T_{\text{Pt}} = 0.5 \text{ }^\circ\text{C}$$

This difference is an estimation of the systematic error of the calibration constant due to heat flow.

It should also be remarked that in all tested configurations the temperature of the Dallas sensor during the heating were higher than during the cooling down. But this effect is probably due to 9-bit readout of the Dallas sensors (sensor stays in different state after heating).

| <i>sensor address</i> | <i>p₀ [°C]</i> | <i>p₁</i> | <i>remarks</i> |
|-----------------------|---------------------------|----------------------|-------------------------------|
| 10F6528E00080097 | -1.4 (1.3) | 1.05 (0.07) | CO ₂ bottle |
| 10B45B8E0008007F | -2.4 (2.6) | 1.12 (0.10) | Xe bottle |
| 106F4A8E000800F2 | -1.5 (2.4) | 1.05 (0.10) | Mixing vessel |
| 10A64A8E000800FB | 0.7 (3.6) | 0.95 (0.15) | |
| 1075738E00080011 | -0.4 (7.1) | 1.00 (0.31) | Very large statistical errors |

Table 1: Results of the calibration for five Dallas sensors. Statistical errors are shown in brackets.

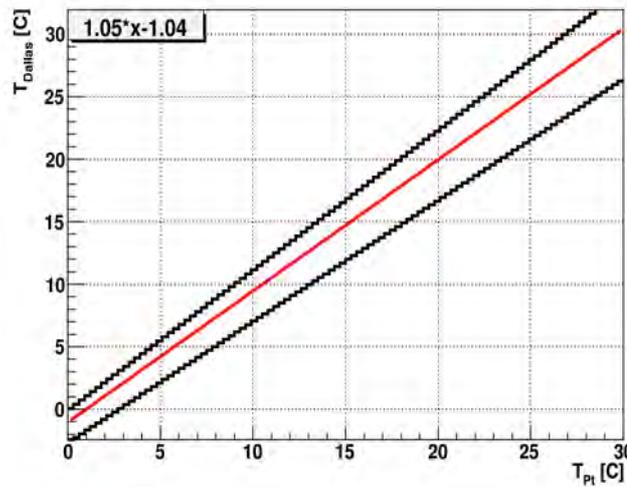


Figure 5. Accuracy of the calibration of sensor 10F6528E00080097 as a function of temperature. The black lines designate calibration error.

6. Conclusions

The calibration of Dallas sensors has been performed however the conditions of the calibration lead to large statistical and systematic errors. Within the obtained accuracy the Dallas sensors are linear with calibration coefficient in a range 0.9-1.1. The calibration constant is found to be in the range -5 to 4.3 °C.

One of the sensor has errors of the calibration two times larger than other sensors.

The main difficulties in reaching a better accuracy of calibration were impossibility to assure stable temperature conditions especially for the second temperature point (warm).

To obtain the calibration of the Dallas sensors with accuracy of 0.5 °C we suggest to perform it before gluing the sensors to the structure.

Bibliography

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