Supplementary material

Measurement of sulfur-dioxide emissions from ocean-going vessels in Belgium using novel techniques

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1. Additional figures and tables

2. Sniffer Quality Management System

2.1. Section S1: Operational manual

2.2. Section S2: Quality assurance

manual 2.3.

Section S3: Data manual

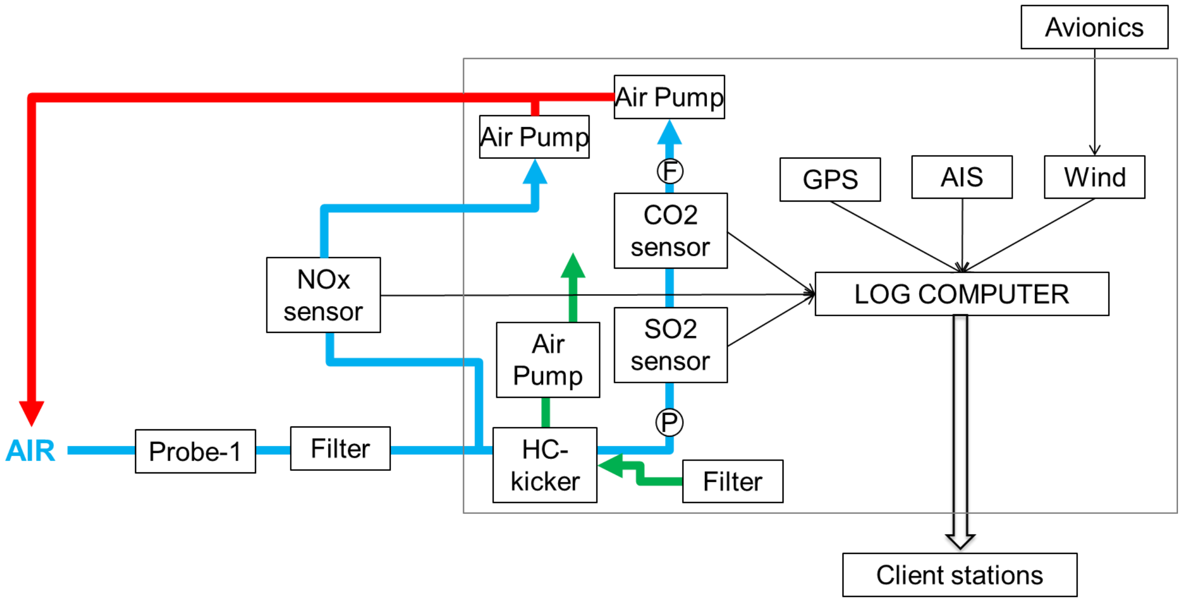
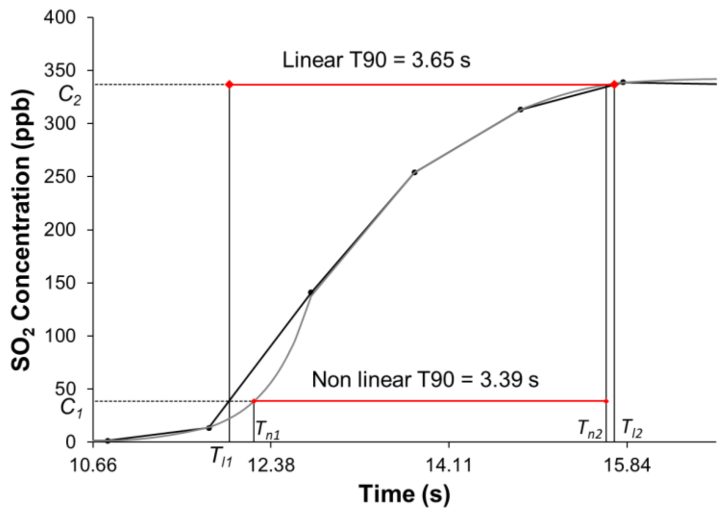


Figure S1. Schematic overview of the updated sniffer sensor system, with NOx sensor and HC kicker.

Figure S2. PTFE sample bag of 50 l filled with 2.5 l of the plume simulation gas mixture and further filled with synthetic air .



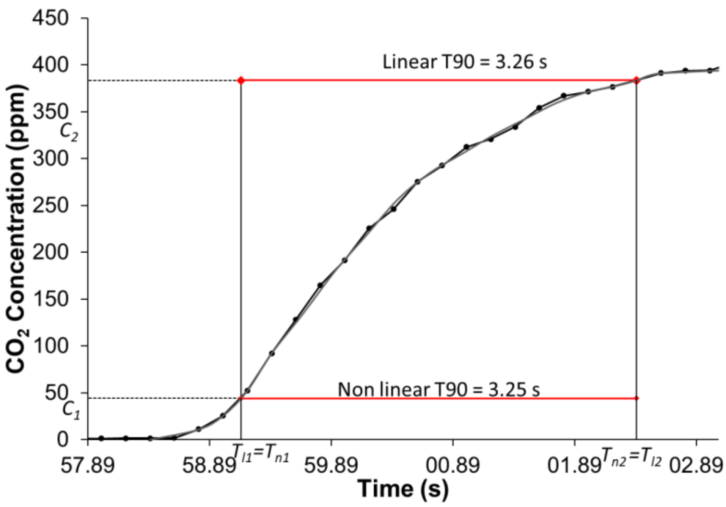


Figure S3. Upper: T90 response times for the Thermo 43i TLE sensor. Lower: T90 response time for Licor 7200 RS. At airflow of 8 l/min.

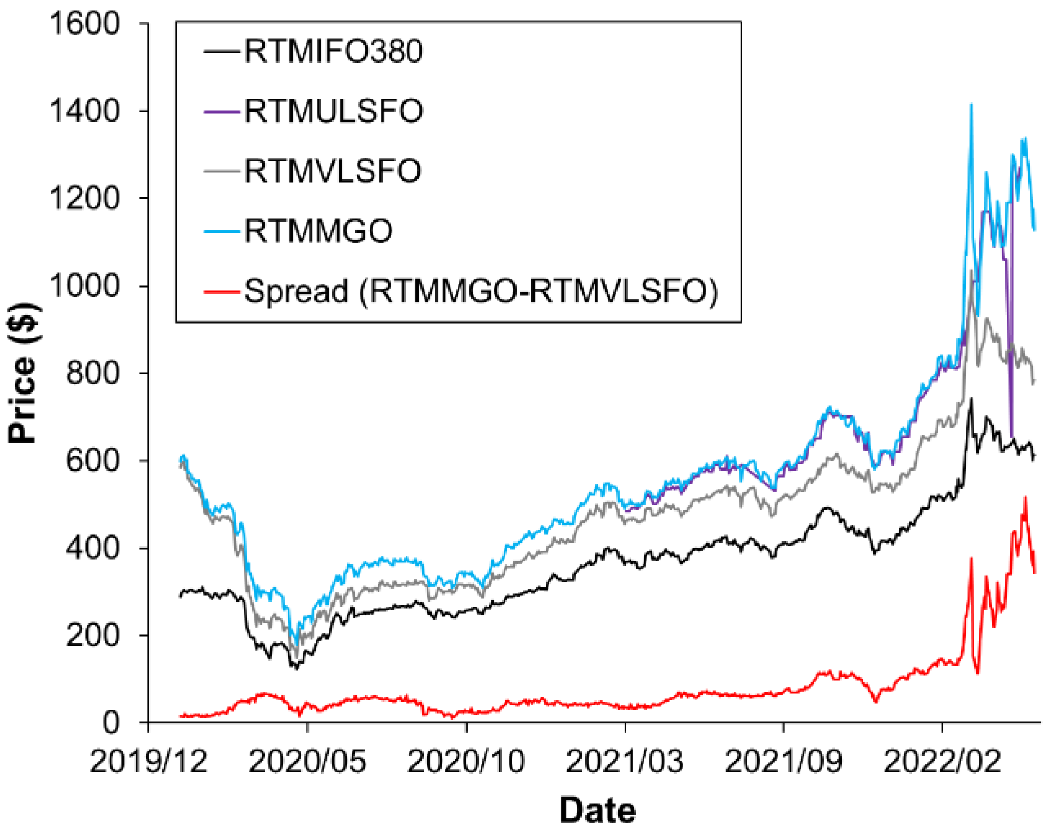


Figure S4. Evolution of the bunker fuel prices for Rotterdam (own visualization based on data provided by Ship and Bunker).

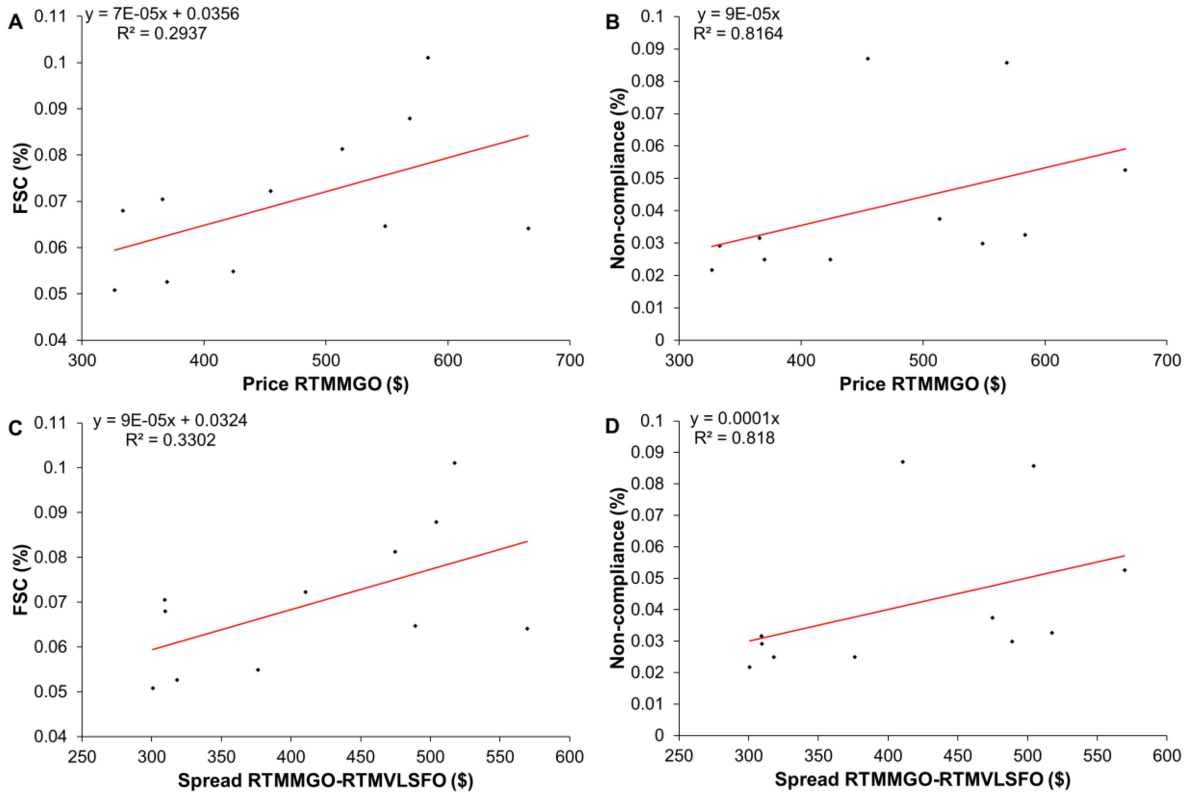


Figure S5. The upper graphs demonstrate the relation between price of MGO in Rotterdam compared to the monthly average observed FSC (A) and the monthly observed non-compliance rate (B). The lower graphs demonstrate the relation between the price difference or spread between MGO and VLSFO in Rotterdam compared to the monthly observed FSC (C) and the monthly observed non-compliance rate (D). For the non-compliance rate an intercept at zero was chosen assuming a zero non-compliance when either the absolute price or the spread is zero.

Table S1. Supplementary uncertainty factors and the combined supplementary standard uncertainty. The uncertainty on the NO/NO_x ISR (80%) is not included as the uncertainty factors as described below are only applied for the non-compliance thresholds (not for the uncertainty on the compliant OGVs). For the potential non-compliant OGVs, NO will be assessed directly without using of the NO/NOx ISR.

Supplementary uncertainties	Max
SO_2 span gas drift (3 months)	2.77%
SO_2 span gas concentration*	0.20%
CO_2 span gas drift (6 months)	0.92%
CO_2 span gas concentration*	0.05%
Measurement accuracy SO_2 sensor	0.40%
Measurement accuracy CO_2 sensor	0.05%
Error on FSC correction (offset reference)	2.35%
Error on FSC correction (offset measured)	2.17%
Error on FSC correction (Slope reference)	2.79%
Error on FSC correction (Slope measured)	4.26%
Uncertainty molar mass S	2.49E-06
Uncertainty molar mass O	1.88E-05
Uncertainty molar mass C	0.01%
Uncertainty molar mass N	2.49E-06
Uncertainty C content in marine fuel	0.83%
Combined supplementary standard uncertainty $\sum u_i^2$	3.17%

** According to gas certificate*

Table S2. Emission ratios for EGCS systems (MEPC, 2015).

Fuel oil sulphur content (% m/m)	Ratio emission SO2(ppm)/CO2(% v/v)
4.5	195
3.5	151.7
1.5	65
1	43.3
0.5	21.7
0.1	4.3

Table S3. Observed colour flags and non-compliance levels for the different zones

2020-21	Average FSC	Green flags	Yellow flags	Orange flags	Red flags	Non-Compliance	Non-compliance orange and red flags
NHTSS	0.064	527	8	6	2	3.0%	1.5%
WHTSS	0.064	291	6	0	2	2.7%	0.7%
Westerschelde	0.080	310	9	0	2	3.5%	0.6%
Rotterdam	0.063	158	0	0	2	1.3%	1.3%
Inter Rot-WH	0.073	96	0	0	1	1.0%	1.0%

SNIFFER QUALITY MANAGEMENT SYSTEM

RBINS-MUMM-SURV

Responsible author: Ir Ward Van Roy

Brussels - 2022

ABOUT THIS MANUAL

The Sniffer Quality Assurance Manual was developed by MUMM to be used with the sniffer installation on board of the Belgian Coastguard Aircraft, a BN Islander (BN2A) with call sign OO-MMM. The manual consists of 3 sections. The sections can be easily accessed from the links in the below table and can then subsequently be browsed from the respective indexes or from the list of Standard Operational Procedures (SOPS). To go back to this page a link is available in the header.

SNIFFER QUALITY MANAGEMENT SYSTEM		
	SECTION 1: OPERATION MANUAL	Sniffer sensor system setup
		Pre flight mission preparation
		In flight mission operation
		Post flight mission operation
		Post flight analysis
	SECTION 2: QUALITY ASSURANCE MANUAL	Sniffer sensor system installation
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	SECTION 3: DATA MANAGEMENT	Internal data structure
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		Reporting compliance data
		Reporting annual results
		Data storage and backup

COMPLETE LIST OF SOPS

SNIFFER QUALITY MANAGEMENT SYSTEM

SECTION 1.

SNIFFER OPERATION MANUAL

REVISIONS

Revision Date	Chapter - section	Page	Description
17/1/2022	Chapter 3 3.2.3	3-8	Update Threshold table
15/2/2022	All		Adding of NOx sensor
25/7/2022	Chapter 2 SOP 1.6	2-10	Adding of plume simulation gas mixture

ABOUT THIS MANUAL

The Sniffer Flight Operation Manual was developed by MUMM to be used with the sniffer installation on board of the Belgian Coastguard Aircraft, a BN Islander (BN2A) with call sign OO-MMM. The Sniffer Operation Manual constitutes to Section 1 of the Sniffer Quality Management System (SQMS). The Sniffer Quality Management System was specifically designed for the Belgian Marpol Annex VI monitoring program, entailing the proper functioning of the sniffer system on board of the Belgian Coastguard Aircraft and the provision of accurate and consistent data collection. The Quality Management System consists of in total 3 Sections, Section 2 - Quality Assurance Manual of the Sniffer system describes in detail the technical specification of the different components of the sniffer and their respective maintenance aspects. Section 3 - Data Management Manuel, consists of the data management aspects (see Figure 1). For every section a detailed manual is developed and available on the Seafile folder “0. SNIFFER QMS” under the Seafile library 05-Instrumentation/05-FluxSense_Sniffer

In this manual, detailed information and step to step instructions are provided about the operation of the sniffer sensor. The manual is organized in different chapters and annexes to provide direct access to specific information, hyperlink bookmarks are used to move to selected objects.

- “**Chapter 1 Sniffer sensor system setup”** describes in brief the sniffer sensor setup on board of OO-MMM aircraft and its components.
- “**Chapter 2 Pre-Flight Mission Preparation”** describes all aspects of the preparations of a surveillance flight, including weather checks and all steps in preparing the aircraft for operation.
- “**Chapter 3 In-Flight operation**” includes the procedures during flight when conducting ship emission measurement operations.
- “**Chapter 4 Post-Flight Mission Operation**” describes all reporting and post flight operation procedures.
- “**Chapter 5 Post Flight Analysis**” Includes basic post flight reprocessing procedures.
- “**Annex A – Technical Fiche OO-MMM**” gives an overview of the coastguard aircraft.
- “**Annex B - Block Diagram**” gives a diagram of the sniffer system setup.
- “**Annex C - Radio communication checklist**” provides the marine VHF questionnaire for NOx.

Figure 1 Sniffer QMS Structure

The sniffer sensor system manufactured by FluxSense (Sweden), consists of a compilation of components from different soft and hardware providers. This manual was composed by the scientific Service MUMM of the Royal Belgian Institute based on the extensive experience of operating the sniffer sensor system on board of the Belgian Coastguard Aircraft and the nature of the Belgian North Sea Aerial Surveillance Program, as a result it is possible that this manual does not fully reflect the official opinion of the manufacturers.

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CHAPTER 1. SNIFFER SENSOR SYSTEM SETUP

The sniffer sensor system is the complete equipment setup used for airborne Marpol Annex VI monitoring executed by the Belgian Coastguard Aircraft. The sniffer sensor system is installed in a BN Islander type B2-A with matriculation OO-MMM.

- BN Islander (with antennas, pitot tube and avionics)
- Sniffer sensor
- NOx sensor (Ecotech)
- Client station (Laptop+VM on Console) with IGPS software

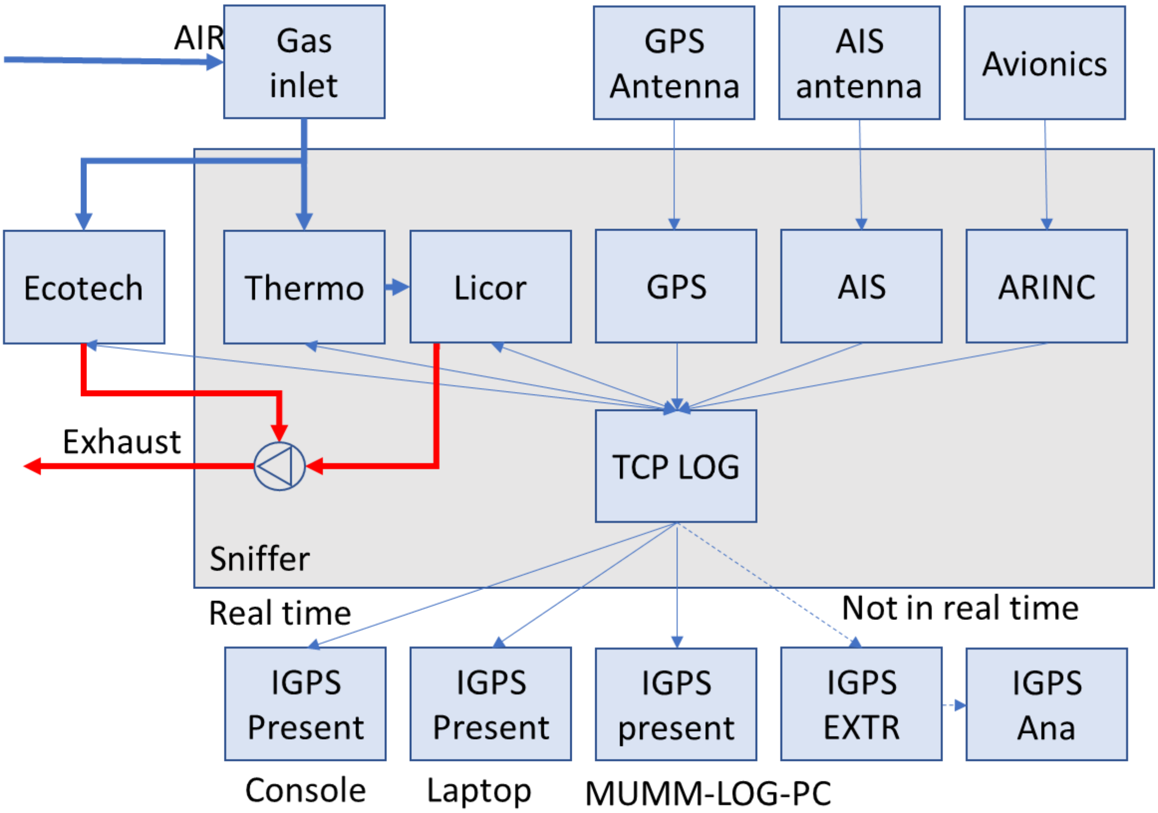

Figure 2 Schematic view of the sniffer setup

1.1. BN Islander

The Belgian Coastguard aircraft OO-MMM is a Britten Norman Islander BN2-B, a twin piston engine propeller aircraft, the two engines provide 300 bhp and 70 Amp of electrical power. The aircraft has a MTOW of 3000kg, can handle 5 persons (2 pilots, 3 observers). The aircraft is a so called high wing aircraft, enabling a good peripherical view. The size of the wings (14m) is relatively long compared to the length (10m), this makes it an excellent STOL aircraft (Short Take-Off and Landing), with very low stall speed (35kts), the fixed and robust landing gear further complete the “island” hopper characteristics. (See **Annex A – Technical Fiche OO-MMM**).

1.1.1 Aircraft power

The Sniffer has an actual power consumption of ca 10 Amp but is connected to a 20 Amp circuit. The sniffer is connected to the "Utilities" bus, a relay connected to the "Survey power" is powering the sniffer, a dedicated Circuit Breaker (CB) (20A) is installed in the cockpit for the Sniffer. A connector for the powering of the sniffer is installed in the ASP connector panel on the left side of the aircraft, behind the sniffer (ASP-CON-07). The sniffer can be switched off by a remote switch on headset connector panel of the main operator. To switch of the EPS for the pumps a switch is installed in the middle of the right side of the console For more information on the sniffer wiring see Section 2 of the Sniffer Quality Management System.

1.1.2 GPU

The Sniffer can be powered on ground by using a GPU (Startpac 53050) connected to the AC external power bus (See Figure 3). An additional connector is installed on the GPU to power the sniffer sensor independent from the AC power supply (connection to the external battery) or outside of the AC (connection straight to the Sniffer sensor 28V input connector).

Figure 3 Start Pac 50 Amp GPU used for powering the aircraft systems on ground

1.1.3 Avionics

The sniffer sensor system is connected to the aircraft avionics, more specifically to the Garmin GTN650 GPS system via Arinc 429. The wind information is provided on labels 315 and 316. Furthermore, an HDMI output on the sniffer internal computer (MUMM_LOG_PC) is connected to the MAP2 of the Avalex AVM 4095 Cockpit display, this allows to present the charts off the IGPS-present (MAP). An addition video input is available on the Garmin G600 for the presentation of the graphs of the IGPS software (SNF) from the Virtual Machine on the Console. An overview of the video signals is provided in Figure 4. More schemes can be found in Annex D of Section 2 of the SQMS.

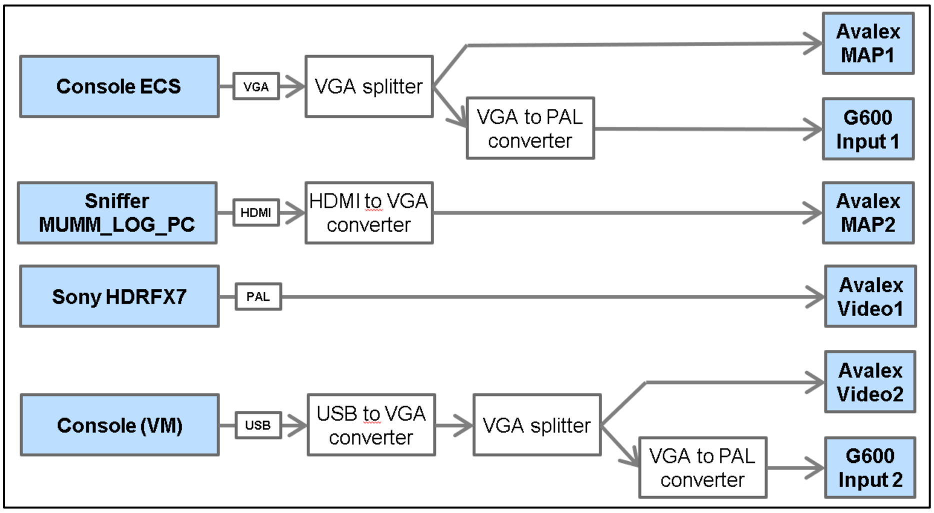

Figure 4 Video signal setup of the avionics

1.1.4 Pitot tube

The gas inlet tube or pitot tube is installed on the bottom of the aircraft, right under the sniffer sensor. The Stainless Steel 3/8-inch tubing is connected to a 1/4-inch PVC tube. That goes straight to the AIR inlet of the filter box.

1.1.5 Filter box

A filter box is installed after the pitot tube, the filter box filters particles and water. A toggle valve is installed in front of the box to switch between AIR mode and ground (GND) mode. When the valve is in GND mode, air passes through a carbon/purafill filter to avoid contamination of the sniffer sensor.

1.1.6 Antennas

The sniffer sensor is equipped with an own AIS/GPS receiver. This receiver is connected via coax cabling to a GPS antenna on the top of the aircraft and an AIS antenna on the belly of the aircraft.

1.2. Sniffer sensor

The main component of the sniffer sensor installation is the sniffer sensor. The sniffer sensor was developed by Chalmers University and commercialised by FluxSense (Sweden).The sniffer sensor is a collection of different components and sensors that are installed in a custom made casing (see also **Annex B - Block Diagram**). The sensors consist of certified equipment used for ambient air quality monitoring that has been disassembled from its original case and reassembled in the sniffer sensor. The different components have been specially adapted for the purpose of airborne monitoring of ship exhausts. Therefore, some components were either reduced in size or removed, also the sample rate of the sensors has been increased to allow high speed continuous air quality measurements on board of fixed wing aircraft. The main sensors are the Thermo 43i TLE for the measurement of SO2 and the LICOR 7200R for the measurement of CO2. The different components are described in detail in Section 2 - Quality Assurance Manual of the Sniffer Quality Management System.

Figure 5 Sniffer 19” Equipment rack

1.2.1 MUMM_LOG_PC

Inside the Sniffer a compact computer is installed (Zotac Nano ID64). This computer collects all the sensor data from the different components and redistributes the log data to the different client stations via Ethernet. Also the IGPS-Present is running on the MUMM_LOG_PC, this is used for the visualisation of the charts to the pilots. The MUMM_LOG_PC can be accessed using TeamViewer or Remote Desktop. For trouble shooting a HDMI or VGA monitor can be connected to the HDMI port and a computer mouse and keyboard can be connected to the USB port.

1.2.2 Sniffer power distribution

The sniffer system uses transforms the 28VDC of the aircraft to 115VAC,

4 circuit breakers are available on the casing of the sniffer:

- CB 1 (5A): External 115V connector (J211) for NOx sensor
- CB 2 (5A): Traco power converters, air pump (1&2) and MUMM_LOG_PC
- CB 3 (5A): NOx airpump (KNF N 022 ATE)
- CB 4 (5A): Thermo 43i TLE

Following internal fuses are included:

- Fuse 1: Inverter 50 A
- Fuse 2: LICOR 2.5A

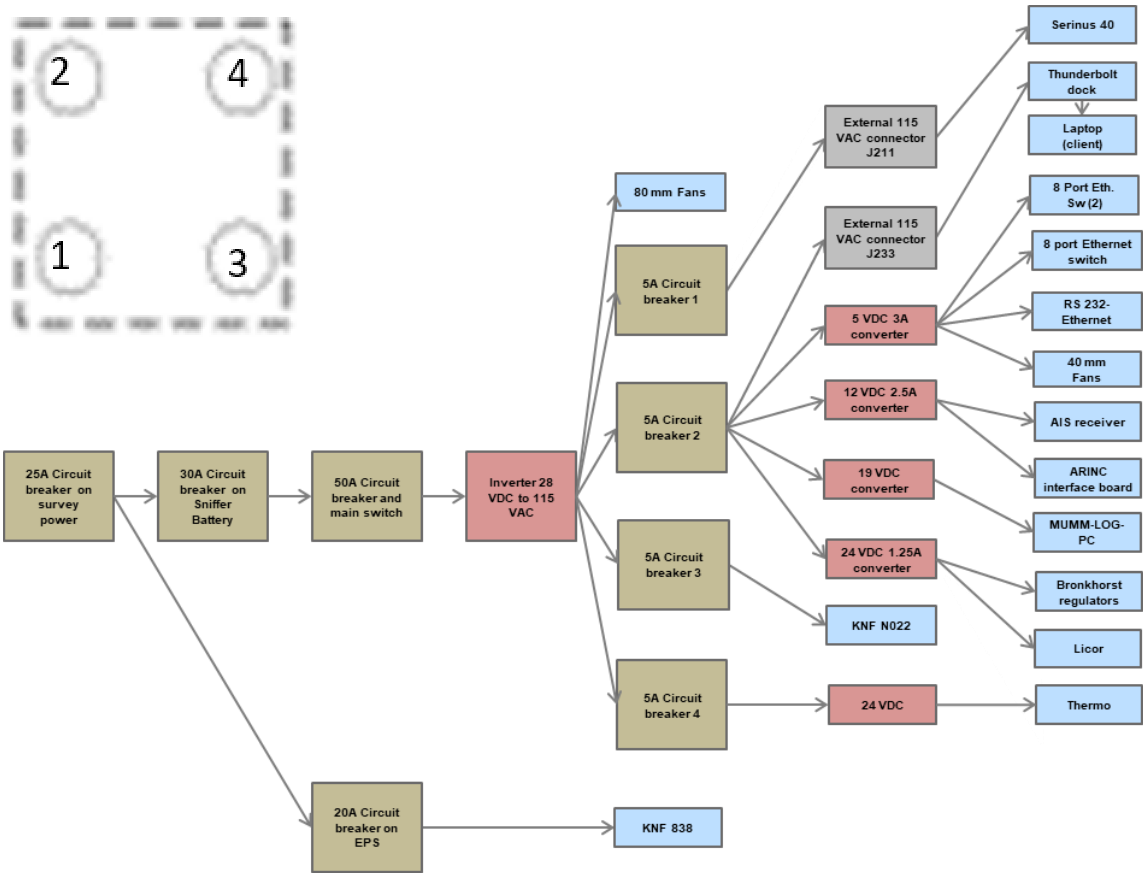

Figure 6 Overview power distribution and circuit breakers inside the sniffer sensor system

1.2.3 Connecting to the sniffer

The Sniffer sensor setup is based on a network environment, all data is logged on the sniffer sensor internal computer MUMM_LOG_PC, this data can be accessed from different client stations following client stations are used during operations:

- MUMM_LOG_PC: for visualisation of the MAP to the cockpitdisplay (on MAP2)
- Operator Laptop: for manual calculation of the FSC
- Console: for strategic overview, guiding pilots and plotting graphs on VIDEO 2 on cockpitdisplay

To connect different client stations to the sniffer sensor a set of predefined IP addresses need to be used (Table 1), for more information on how to set the IP address see Section 3 of the SQMS.

Table 1 IP addresses for external connection to the sniffer sensor

IP addresses	User
192.168.1.230 -239	available
192.168.1.240	Console via VM
192.168.1.241	PC Ward via Thunderbolt dock
192.168.1.242	PC Kobe via Thunderbolt dock
192.168.1.243	PC Annelore via Thunderbolt dock
192.168.1.244	PC Benjamin via Thunderbolt dock
192.168.1.245	PC Ward via cable
192.168.1.246	PC Kobe via cable
192.168.1.247	PC Annelore via cable
192.168.1.249	PC Benjamin via cable

1.3. NOx sensor

A NOx sensor was added to the sniffer sensor system. The sensor is an Ecothech Serinus 40. The sensor is installed in the back of the aircraft. A protection plate is installed in the front of the sensor protecting it from accidental touches on the control buttons. All commands go through a smartphone with the Serinus application connected through Bluetooth.

Figure 7 NOx sensor installed in the rear luggage compartment (here displayed without the protective front panel)

1.4. Client station

In theory a vast amount of client stations can be connected to the Sniffer by using ethernet. For operational use, only 2 client stations are connected to the sniffer. The first being the console and the second being the operator laptop via Thunderbolt dock. This means that together with the MUMM_LOG_PC constantly 3 computers are receiving the sensor data and can be used for navigation and analysing the measurements.

1.4.1 Console (MMU)

The MMU is the main console in the aircraft used for the Medusa system. The MMU runs on a tailored Open Suse Linux Platform and is therefore not suited for the installation of the IGPS software. A Virtual Machine (VM Player) with a Windows XP installation is installed on the MMU to allow to run IGPS on the console.

To enable direct Ethernet connection from the VM to the Sniffer sensor an additional Ethernet cable was installed (from J221 to an Ethernet hub inside the console). The IGPS software is installed on the “C:” drive of this VM XP distribution. The firewall has been deactivated for the IGPS software.

An additional USB to VGA adapter is installed on the VM. This allows the presentation of the VM display (SNF view of the AISPresent.exe) to the cockpit display and G600 (Video 2).

1.4.2 Laptop with RAM mount and WiGig dock

The operator laptops (Dell Lattitude 5420) have been specially selected and purchased for the conduction of sniffer flights. A special RAM laptop mount has been installed on the right side of the cabin to allow the laptop operator to work freely. To avoid issues with multiple cables a Startech thunderbolt docking station has been installed on the front side of the console, the laptop is connected to a 2 m thunderbolt cable providing, data (ethernet, USB, HDMI) and power. The thunderbolt dock and laptops are powered by 115V power connector on the Sniffer (J233).

Figure 8 RAM mount for installation operator laptop

1.4.3 IGPS software

The IGPS folder is installed on the "C:" drives of the operator laptops and are synched through Seafile on all the operator laptops. This way all operators use the same software version and have the same emission data. The different software directories and files are:

- "Charts" Directory: folder with Open source charts of the world
- "Missions-Data" Directory: folder with generated reports of observations
- "MAIL" Directory: not used by SURV
- "AIS_EX8.exe" program: tool used for extraction of TCP-LOG files
- "AISPresent.exe" program: main software program used in flight and during calibrations
- "IPGSAna44.exe" program: software for post flight analysis (extraction required)
- "AISPresent.ini": this is the settings file for AIS present (can be read and edited using Notepad)
- "IP-configuration-SURV.txt" file: this document contains the used IP addresses for the different clients
- "Emissiondata_xxx.txt" files: are generated by the different clients (ODN-WVR, ODN-KS, ..) and contain the FSC measurements
- "Mail_Sniffer_SO2_Man_Meas.csv" file: contains the evaluation (High/Low/Not detected) of the manually marked ships
- "Comments _xxx.txt" contain the stored comments (old comment files are stored in "Comments" directory
- "wakeuplan.txt" file: contains the Mac address of the MUMM_LOG_PC in the sniffer sensor and can be used to wake up by lan
- "Optical_SO2_Man_Meas.txt" file: not used by SURV
- "STATICSHIPDATA_xxx.txt" file: contains a record of the observed ships per operator
- "borlndmm.dll", "cc32230.dll", "cc32230mt.dll", "Fetchlog.txt", "Logfile.txt", "Memo1-1.txt": are other additions files
- MMSI_Date: This file contains the Keel Laying Dates of tens of thousands of ships

The data storage, data processing, … is described in detail in Section 3 of the Sniffer Quality Management System.

CHAPTER 2. PRE-FLIGHT MISSION PREPARATION

In this chapter all the preparatory operational aspects about conducting sniffer flights are described, from the mission planning starting one day before the flight, up to the last preparations just before take-off.

2.1. Flight planning (12 am, 1 day before take-off)

2.1.1 Weather minima check

It is recommended to only plan MARPOL Annex VI monitoring flights with favourable meteorological forecasts, Visual Meteorological Conditions (VMC) conditions are required for conducting sniffer flights. Obviously, weather conditions should be followed up by operators and pilots before and in flight and flights should be cancelled in case the weather conditions become unfavourable.

SOP 1.1. Weather check

1. **Wind speed**: maximum wind force of 30 kts at sea, a forecasted maximum windspeed of 25kts in EBOS is a practical threshold, but not conclusive.

Note: A small amount of turbulence is often felt when passing through a smoke plume, which in a way gives a good indication for the crew to recognize the moment when the aircraft flew through the plume to sample the exhaust gases. Certain ships however, for instance roll-on/roll-off (RORO) ships may provide severe turbulence downwind of the ship. When flying too close with strong winds this may result in turbulent ship approaches. This turbulence effect depends on the physical characteristics of certain ships: the impact of the structure of the ship on the wind may cause a strong "mechanical" turbulence, such as with RORO ships. For such types of vessels, this mechanical turbulence can already be severe during wind conditions of 25 kts (especially with crosswind). This aspect should be kept in mind when selecting vessels for compliance monitoring under strong wind conditions.

2. **Visibility**: a minimum visibility of 5 km
3. **Cloud coverage:** clear of clouds, furthermore it is advised to have a cloud base at least 200 ft higher than the cruising altitude (ca at 600-700 ft).
4. **Precipitation**: light precipitation should not pose any problems for the monitoring, but heavy rain, snow or hail can result in low visibility or clogging of the sensor filters and should therefore be avoided.

Note: Rain may reduce the FSC measurements by 20-30% because of the washing out SO2.

5. **Temperature:** no measurements can be made during icing conditions, so during humid and freezing conditions.
6. **Inversion layers**: in normal conditions, air temperature decreases with altitude. But when air temperature increases at a certain altitude an inversion layers may occur. Weather forecast do not give any information of the occurrence of inversion layers, but this typically happens with wind-still cloud-free conditions during summer. At an inversion layer, air pollutants concentrate and form smog. If these inversion layer occurs at low altitude (<500 ft) they may interfere with FSC measurements as the background values for CO_2 and SO_2 may not be stable

in this case a change in the flight route or planning might be necessary. For instance, the monitoring could be shifted to another area or the afternoon (more stable atmosphere).

2.2. Flight routing

Optimally the organisation off the Sniffer flights is spread over the year to maximise the enforcement efficiency and reduce redundant measurements, nevertheless as the conditions during winter are less favourable it is recommended to organise the sniffer flights from March until October.

For the flight planning of missions over the Belgian and neighbouring waters, one sniffer flight of up to maximum 3 hours per day is recommended, as an alternative two shorter flights may be organised as well, but in this case, it is advised to maximise the time between the 2 flights. The standard template (OO-MMM_FLIGHTPLANNING (Date).xls) should be used for compiling the Flight planning (available on seafile "11-SURV-Planning\01-Flight\YEAR\Flight"), after finalising the template a PDF should generated and send to the national contact points including PSC in Belgium (sulphur@mobilit.fgov.be) and Netherlands (psc@ilent.nl) and the maintenance company Styl Aviation (OO-MMM@stylaviation.com), make sure that "Pollution (Sniffer)" is selected at mission type (see Figure 10).

The official Bonn Agreement waypoints should be used for planning a flight routing, focusing on shipping lanes and other zones of interest (e.g.port entry zones). Flight routing for the MARPOL Annex VI monitoring is very susceptible for changes in flight as in practice the flight route depends on the presence of ships. Therefore, it is required to use dynamic flight routes (see example in Figure Figure 9) based on predefined waypoints, but where the routing is adapted in flight to maximize the number of monitored ships.

To make sure no communication problems occur with the ATC's it is advised to include a larger area in the flight planning than the actual envisioned routing (e.g. including the complete NHTSS from NH to FB2). For the planning of flight routes over Dutch waters it is advised to focus on the shipping lanes to and from Rotterdam (waypoints: NN1-NL11-NL7 and Maas Center) (see Figure 11)

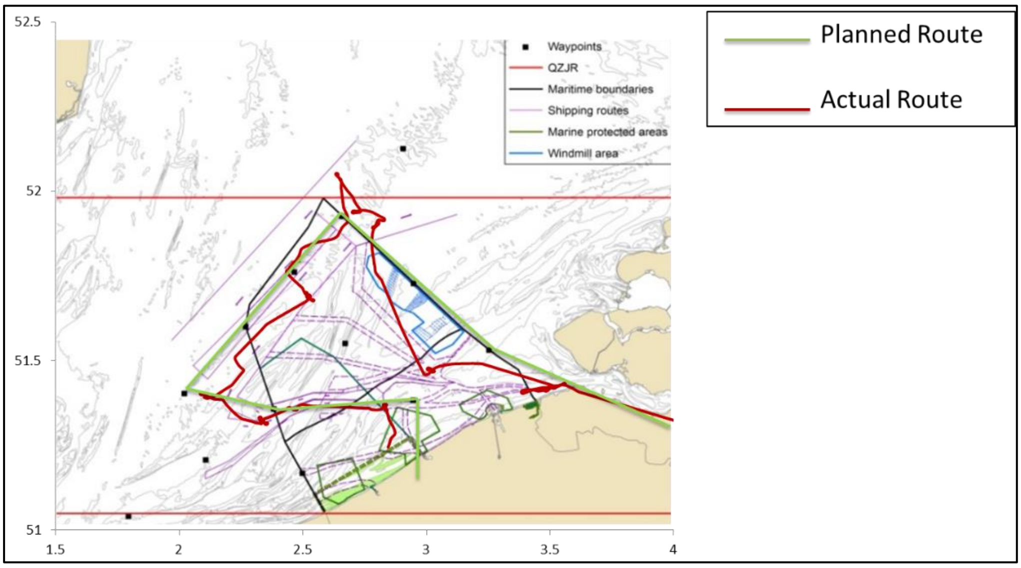

Figure 9 Example of planned and actual route of a MARPOL Annex VI monitoring flight in BE waters

BMM
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OO-MMM FLIGHTPLANNING

ORIGINATOR OF THE PLANNING

Date / Time: 09/04/18 08:33	Flight operator's name **SCHELDEMAN Kobe**	Mobile:	+32 476 52 89 95

EMAIL RECIPIENT LIST

Pilots	De Prest Paul Pieter Janssens		
Others	MIK MIK@mil.be Styl OO-MMM@stylaviation.com FOD Leefmilieu marien.milieu.marin@environment.belgium.be BMM Brussel surv@naturalsciences.be DZV inspectie.zeevisserij@vlaanderen.be	NL Nat. Focal Point BE PSC Env. Adm NL PSC	planning@kustwacht.nl / ccc@kustwacht.nl sulphur@mobilit.fgov.be psc@ilent.nl

GENERAL INFO

Weather predictions	**Date**	10/04/18	**Time**	12:00 UTC	**Place**	Westhinder		
	Wind	ESE	**Force**	4 bft	**Waves**	80 cm		
Low Tide	**Time**	14:28 UTC	**Place**	Ostend				

FLIGHTINFO

Total number of Flightdays		2	**Time**	ca 7:00 h
Total number of Flights/day	**Day1**	2		
	Day2	2		

DAY1: Tuesday, 10 April 2018

Flightnumber	18045			
Missions	Transit		Pollution Control (sniffer)	
Pilots	DPT	JNS		
Operators	KS	RS		
Take-off	14:00 LT			
Altitude	150-500 Ft			
Route	EBAW-Westerschelde-B7-B6-NH-B5-B4-B3-UKB-FB2-B2-B0-EBOS			
Duration	ca. 2:30 h			
Meeting before flight with:	Crew		Time 12:30 LT	Place Lindsky Deurne
Actions after flight	Refuelling			

Figure 10 Example of Flight planning for Sniffer flight

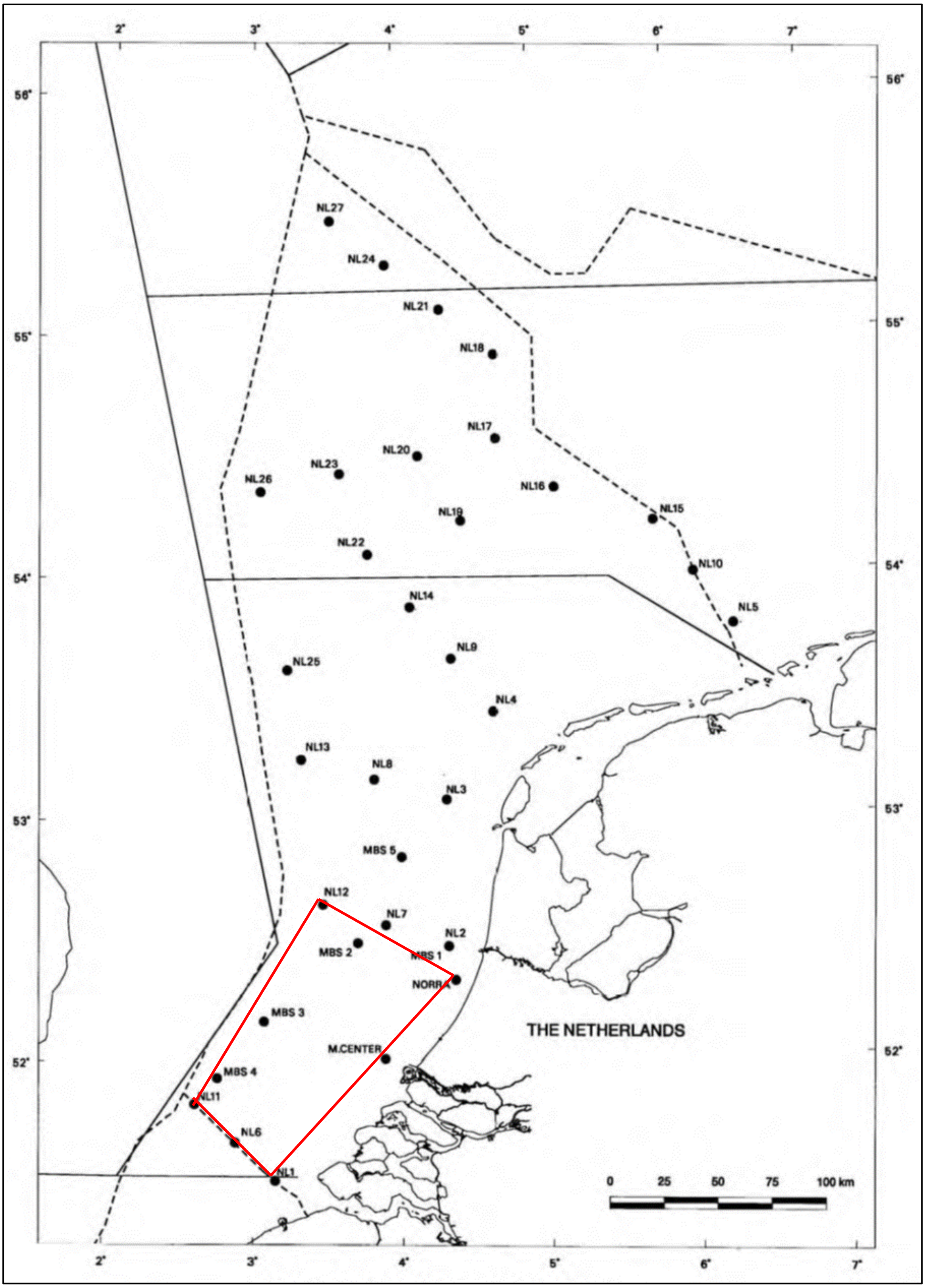


Figure 11 Dutch BA waypoints and main zone of interest (red)

2.3. On ground procedures before mission start (3hr before take-off)

The gas sensors used in the sniffer sensor systems are not stable in time and measurement results may vary according to environmental conditions (temperature, humidity, …), therefore detailed calibration and maintenance procedures have been described **Section 2 of the Sniffer Quality Management System**. Before every mission the sniffer software should be calibrated, therefore the basic procedures are provided in this section of the QMS. In case a hardware calibration is needed or in case the gas cylinders need to be calibrated, **Section 2 of the SQMS** should be consulted.

SOP 1.2. Power on Sniffer with GPU

1. Connect power extension cord (if operated in Ostend, place cable protector)
2. Connect GPU to external power input on sniffer battery, power on GPU,
3. Battery-switch must be turned in “External” mode towards the nose of the AC (LED light is ON)
4. Toggle the sniffer-switch at console operator seat (at intercom jacks)
5. Toggle the EPS switch of the sniffer pumps (right side of the console)
6. Check circuit breaker on emergency sniffer battery (must be pressed in)
7. Check the power use on the GPU (must be lower than 30amp at startup)

Note: when the sniffer battery is fully drained and/or the sniffer is powered through the AC circuit instead of the EXT circuit, leave the pumps off for 1 hour after system startup

SOP 1.3. Laptop installation

1. Install laptop in RAM mount and connect thunderbolt
2. Switch on laptop
3. Connect to MUMM_LOG_PC using Teamviewer (V12) use 192.168.1.9 (make sure Teamviewer accepts LAN connections) and pwd: “mumm”
4. On personal Laptop open SQMS-Follow-up.xlsx on Sniffer data>>Calibration, in the header of the different active gas components (CO2-1(#), CO2-2(#), SO2 (#), NO (#)) it is indicated if a software calibration, hardware calibration or Gas cylinder calibration is required.

Note: Sniffer has to be warmed up at least 60-120 minutes before every calibration and sniffer flight. For NOx: check the error log MAIN MENU>>Analysier State Menu>>Status Menu status>>show error list OR press on the orange light with a narrow pen. In case “Instrument warm-up” is indicated, the sensor is not yet ready- the sniffer should not be switched off from the moment the software calibration is done until the end of the mission (even if the mission is spread over several days).

SOP 1.4. Software calibration

1. Put chart with cylinders next to aircraft (ca 3 m)
2. Connect flexible hose to pitot tube via Swagelok 3/8 with inner Nylon ferrule (tighten finger tight and use 3/4 wrench to tighten 1 quarter)
3. Set the carbon filter below the pilot seats from “Ground” to “Air” mode
4. Open SQMQ followup file 0. QMS\2. SNIFFER QA\QA_Follow-up
5. Open gas sheets (green tabs) and go to gas sheets
6. Enter date in first column, use Ctrl+; as shortcut
7. Check if the ref concentrations matches the reference gases (indicated in writing on cylinder)
8. Open IGPS Real (on MUMM_LOG_PC using Teamviewer)
9. Go to SNF in IGPS Software
10. Open calibration for CO2, if none present create new one (Figure 14)

  - **a.** Select “Main component”: CO2
  - **b.** Check concentration and edit if necessary (300-450 **ppm**)
  - **c.** Set “Time”: 60 Sec

11. Open gas cylinder valve

12. Connect flexible hose to CO2 reference gas cylinder via Swagelok 1/4” (tighten fingertight and turn 1 quarter with a 7/16 wrench)
  - **a.** Check pressure of the gas bottle on first manometer (min 10 bar)
  - **b.** Check pressure of the output on second manometer (must be 2 bar)
  - **c.** Check if over flow is 0.6-0.08 l/min, if necessary adjust volume (ca 9-11 l/min)
  - **d.** Check reading of CO2 on IGPS software (check also if SO2 is zero)
  - **e.** Check reading on IGPS, wait (60 sec) until stable

13. On IGPS software start calibration (green light appears)

14. After calibration (60 seconds) a comment will be shown in comment log

15. Disconnect the flexible tube

16. Close cylinder valve and fill in end pressure in active CO2-sheet in SQMS-Follow-up.xlsx

17. Repeat steps 11-16 for the second CO2 gas mixture

18. Open SO2 (#) sheet and enter date (use Ctrl+;)

19. Check if the ref concentration matches the SO2 reference gas

20. Go to SNF in IGPS software

21. Open calibration for SO2, if none present create new one (see Figure 14)
  - **a.** Select “Main component”: SO2
  - **b.** Check concentration and edit if necessary (300-400 ppb)
  - **c.** Set “Time”: 120 Sec

22. Open gas cylinder valve
  - **a.** Connect flexible tube with the SO2 reference gas cylinder via Swagelok 1/4” (tighten finger tight and turn 1 quarter with a 7/16 wrench)
  - **b.** Check pressure of the gas bottle on first manometer (min 10 bar)
  - **c.** Check pressure of the output on second manometer (must be 1.5 bar)
  - **d.** Check if overflow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
  - **e.** Check reading of SO2 on IGPS software
  - **f.** Check reading on IGPS, wait (60 sec) until stable (check also if CO2 is zero)

23. Select “Start calibration”
  - **a.** green light appears
  - **b.** message appears: merge with old calibration: click “yes”

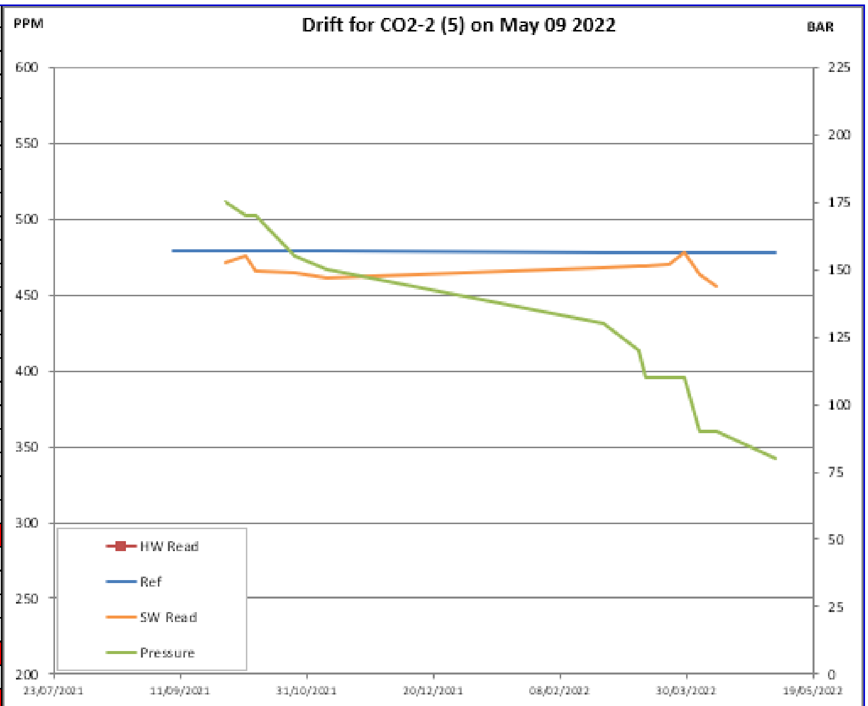
24. After calibration (120 seconds) a comment will be shown in comment log

25. Disconnect the flexible tube

26. Close cylinder valve and fill in end pressure in SO2-sheet in SQMS-Follow-up.xlsx

27. go to Settings>>Utilities and check “k” and “o” for SO2 stream and Licor 7200 - CO2 and copy these calibration factors to the SQMS-Follow-up.xlsx sheets (see Figure 15)

Manufacturer	Airplus
Gas botle ref	JA95ND8
MUMM reference	CO2-2 (5)
Purchase date	
Delivery date	
Start date	06/08/2021
End Date	
Duration	276 Days
Requested concentration	470.0 PPM
Commercial concentration	479.4 PPM
Warranty	22/05/2026
Error absolute	
Error percentage	0.500%
Actual error	0%
Traces of SO2	0.0 PPB
Traces of NO	0.4 PPB
Traces of NO2	0.0 PPB
Nr of calibrations for 50 bar	
Pressure for GAS calibratio	7.3
Date of last HW calibration	04/05/2022
Date of last gas calibration	21/02/2022
Date of last HW Check	27/01/2020
SW calibration needed	Yes
HW calibration needed	No
Referene Gas Drift	0.15%
Software drift	1.32%
Sensor drift	Data Missing
Gas calibration warning	Yes
Gas +1 calibration warning	
HW check needed	Yes



Date of calibration	REF	Software		Hardware		Pressure
		SW k-factor	SW Offset (o)	HW Read	HW Zero	
14/03/2022	478.0 PPM	1.010	4.500			110 Bar
23/03/2022	478.0 PPM	1.006	5.100			110 Bar
29/03/2022	478.0 PPM	1.000	0.000	477.0 PPM	0.5 PPM	110 Bar
04/04/2022	478.0 PPM	1.020	5.300			90 Bar
11/04/2022	478.0 PPM	1.028	9.586			90 Bar
04/05/2022	478.0 PPM			478.0 PPM	-0.4 PPM	80 Bar

Figure 12 Print screen from the SQMS-Follow-up.xlsx file

Figure 13 During calibration the aircraft is powered with the GPU connected to the Power input (A) and the Switch (C) set to "EXT", the led indicator will light up when the battery is receiving power (B)

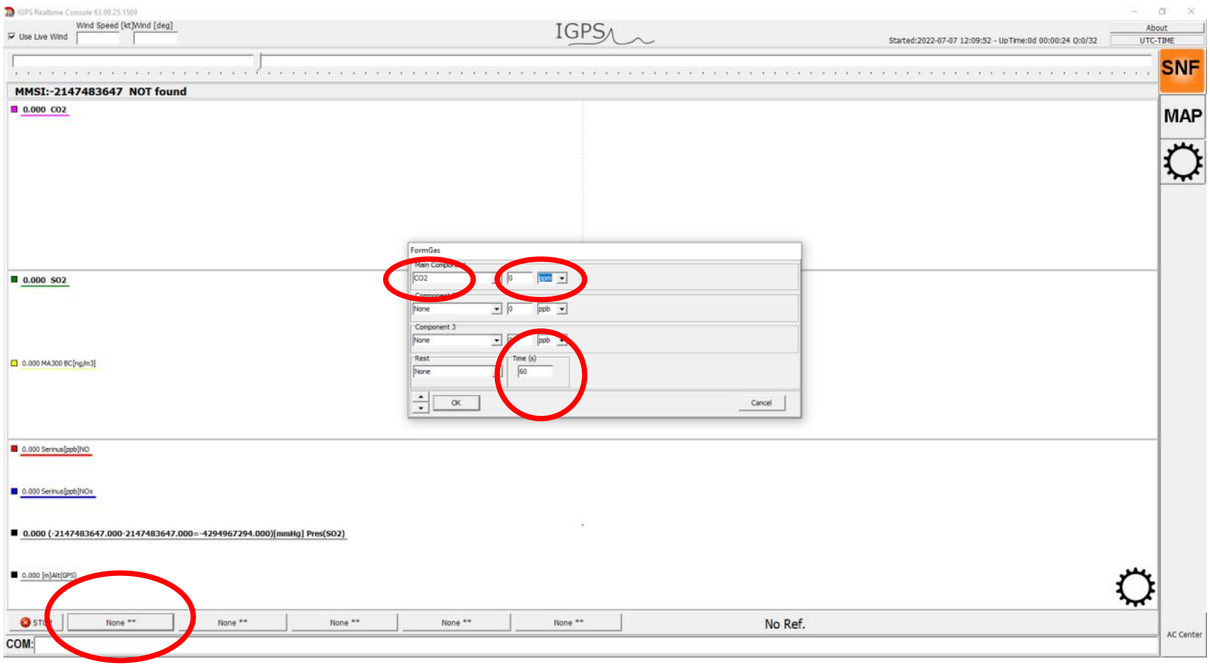


Figure 14 To start new calibration setting, select "None" in "SNF" view, a pop-up window will open, select the component (SO2 or CO2) enter concentration (in ppb or ppm) and select time (120 sec for SO2; 6O sec for CO2)**

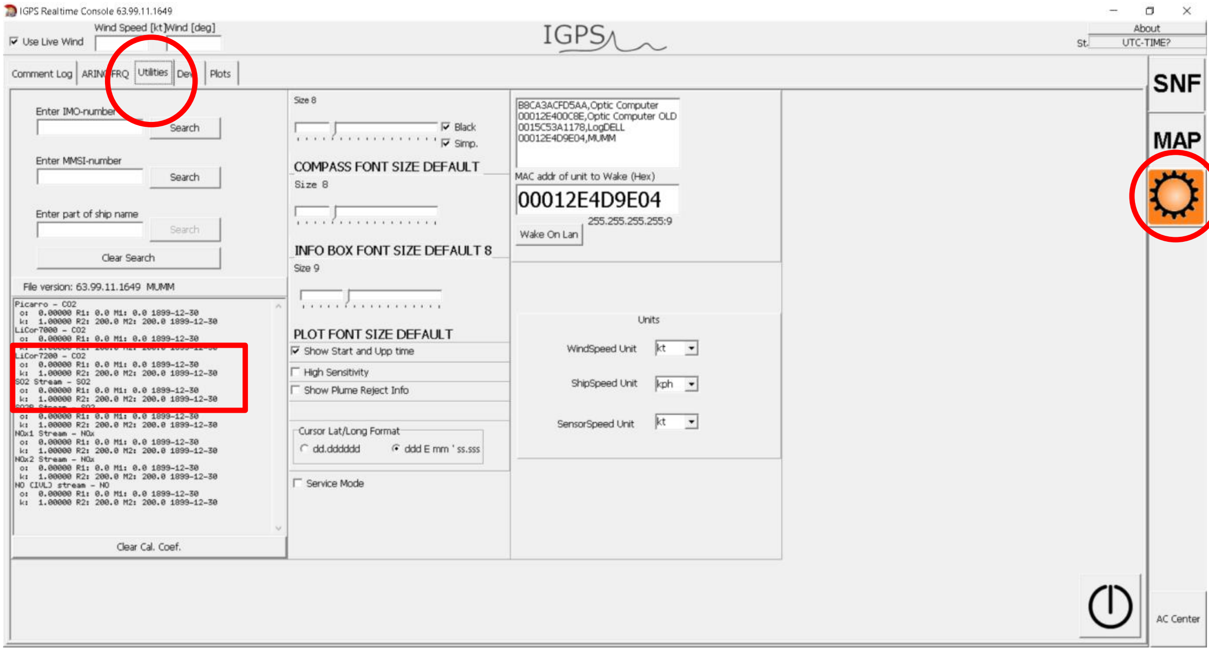


Figure 15 After (complete) calibration the new calibration factors (k and o) are visible under settings view (cog wheel) under "Utilities" tab

The NOx sensor requires a hardware calibration. The calibration gas mixture is NO in nitrogen, this mixture is used for both the NO as the NOx calibration.

SOP 1.5. NO hardware calibration

1. For the NO calibration connect the smartphone to the Serinus
   a. Open Serinus application
   b. Click connect
   c. To improve the connection keep the device close to the sensor
2. Set the sensor to "all mode"
   a. Quick menu
   b. Gas to measure
   c. Set to "All"
3. Set Sensor to 30 second averaging time
   a. Go to Main Menu>>Measurement menu
   b. Go to Filter
   c. Set to 30 s filter
4. Open synthetic air gas cylinder
5. Connect flexible tubing to the Synthetic air gas supply
6. Write down the concentration of NO (zero)
7. Go to Calibration menu
   a. Main Menu >> Calibration menu
   b. Scroll down to zero NO
   c. Click select >> if an error message appears click "confirm"
   d. Scroll down to Zero NO2
   e. Click select >> if an error message appears click "confirm"
8. On the IGPS SNF graph look at the NO and NOx signal, If both NO and NOx stay within +/- 5 ppb continue otherwise repeat step 33
9. Disconnect synthetic air from flexible hosing, close the cylinder valve

10. Open NO gas cylinder
11. Connect flexible tubing to the NO gas supply
12. Write down the NO concentration (span)
13. Go to Calibration menu
    a. Main Menu >> Calibration menu
    b. Scroll down to Span NO
    c. Check if the concentration matches with the concentration on the cylinder and SQMS-followup.xls file
    d. Wait 1 minute
    e. Click select
    f. Scroll down to Span NOx
    g. Check if the concentration matches with the concentration on the cylinder and SQMS-followup.xls file (NO+NO2 concentration)
    h. Wait 1 minute
    i. Click select

Note: NOx signal must always be (slightly) higher than NO

14. On the IGPS SNF graph look at the NO and NOx signal, If both NO and NOx stay within +/- 5 ppb of the reference and NOx>NO, continue otherwise repeat step 39
15. Disconnect NO from flexible hosing, close cylinder valve
16. Set the filter back to none
    a. Go to Main Menu>>Measurement menu
    b. Go to Filter
    c. Set to “none “
17. Set the sensor back to NOx
    a. Quick menu
    b. Gas to measure
    c. Set to “NOx”
18. Write down the span and zero concentration in the SQMS-Follow-up.xlsx file

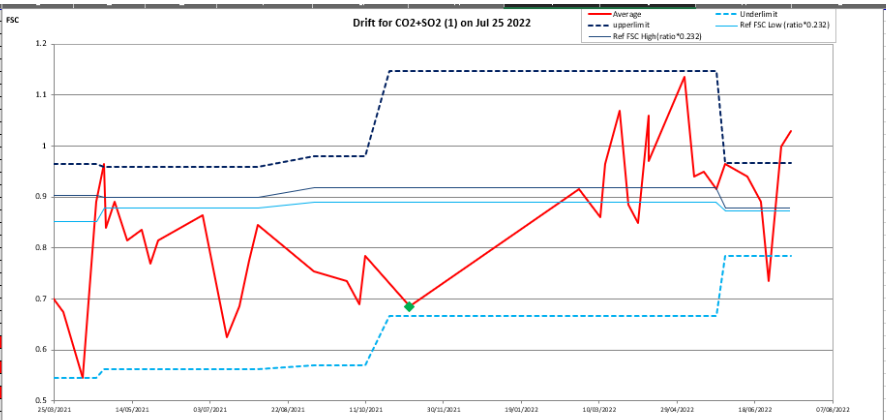
At the end of the calibration procedure the sniffer sensor is tested with a gas mixture of CO_2 and SO_2 in synthetic air simulation a high FSC plume (ca. 1% FSC).

SOP 1.6. Plume simulation mixture check

1. Make sure the background values are stable for 1 min
2. Keep the opening of the tubing upwind, avoid breathing out close to the tubing end
3. Place the plume simulation mixture cylinder with the opening downwind
4. Open the cylinder valve, check the pressure
5. Release a few sudden bursts of gas to purge the regulator
6. Hold the opening of the tubing a few cm in front of the regulator
7. Open the toggle valve for <1 sec
8. Check if the values for SO2 and CO2 are within limits
    a. CO2 should be below 2000 ppm
    b. SO2 should be below 2000 ppb
    c. Clear peaks no background

9. Conduct a FSC measurement (see 3.3.1) and link the measurement to the emulated AIS detection in the equator
10. Wait 1 min
11. Repeat steps 6-10 two more times
12. Write down the highest and the lowest of the two measurements in xls file sheet CO2+SO2
13. The updated FSC span and offset are displayed in column K and J
14. Check if the measured FSC falls within the acceptable limits
    a. On graph the average FSC (Red line) must fall withing the dotted lines
    b. The FSC values that fall outside the limit will be highlighted in red
15. In case the average values falls outside the limits, the new span and offset must be entered in the ini file for all IGPS stations used for the measurements (1 operator laptop + MUMM-LOG-PC)
    a. Close IGPS present
    b. On MUMM-LOG-PC only: close watchdog and close IGPS present again
    c. Open C:\IGPS\AISPresent.ini
    d. Scroll down to:
    e. ….
    f. FSC_Span = 1.2571
    g. FSC_Offset = 0.0007
    h. ….
    i. Replace the old span and offset values with the new offset and span values
    j. Save the AISPresent.ini file
    k. On MUMM-LOG-PC reopen watchdog from C:\IGPS\WatchdogIGPSpresent
    l. Set the value in column K to "Y"
    m. Open C:\IGPS\Thresholds, BIAS and SFOC-2022.xls go to sheet "FSC→Bias correctie"
    n. Enter flight number and date
    o. Copy the new FSC span and offset values
16. In case the average FSC value does not fall outside the limits
    a. Set the value in column K to "N"

Manufacturer	Airliquide
Gas botle ref	L0P8RCE
MUMM reference	CO2+SO2 (1)
Volume (l)	10 L
Purchase date	10/05/2019
Delivery date	03/07/2019
Start date	23/10/2019
End Date	
Duration	1006 Days
Requested concentration	1.16 %FSC
Commercial concentratio	0.00 %FSC
Warranty*	18/06/2020
Error absolute	#DIV/0!
error percentage	#DIV/0!
Actual error	#DIV/0!
Traces of NO	60.0 PPB
Traces of Nox	2,750.0 PPB
SO2 (pppm)	1,148.0 PPB
CO2	301.0 PPM
Bias relatief	1.16
Bias absoluut	0.0057
Median FSC AC	0.05
Median FSC PSC	0.0600
Span FSC	1.22
Offset FSC	0.0044
Date of last Gas Callibratio	25/05/2022
Plume Bias Check neede	Yes
Re-calibration needed	No
FSC Span adjustment ne	Yes
Referene Gas Drift	3.19%
Gas calibration warning	Yes
Gas +1 calibration warning	No
FSC NO error	0.00026



Date of software calibration	Ref FSC Low (ratio*0.232)	Ref FSC High(ratio*0.23	Underlimit	upperlimit	FSC min FSC	FSC max FSC	FSC Average	Span (FSC)	Offset (FSC)	Replacement Span and offset	Pressure
16/05/2022	0.89 %FSC	0.92 %FSC	0.67 %FSC	1.15 %FSC	0.90 %FSC	1.00 %FSC	0.95 %FSC	1.0953	0.0078	N	65 Bar
24/05/2022	0.89 %FSC	0.92 %FSC	0.67 %FSC	1.15 %FSC	0.89 %FSC	0.94 %FSC	0.92 %FSC	1.1401	0.0056	N	65 Bar
30/05/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.89 %FSC	1.04 %FSC	0.97 %FSC	1.0411	0.0106	Y	65 Bar
13/06/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.91 %FSC	0.97 %FSC	0.94 %FSC	0.9644	0.0152	N	60 Bar
22/06/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.86 %FSC	0.92 %FSC	0.89 %FSC	1.0225	0.0117	N	55 Bar
27/06/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.70 %FSC	0.77 %FSC	0.74 %FSC	1.2571	0.0007	Y	50 Bar
05/07/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.97 %FSC	1.03 %FSC	1.00 %FSC	1.0917	0.0080	N	
11/07/2022	0.87 %FSC	0.88 %FSC	0.79 %FSC	0.97 %FSC	0.99 %FSC	1.07 %FSC	1.03 %FSC	1.0568	0.0098	N	

Figure 16 SQMS-follow up file with CO2+SO2 sheet

2.4. Before take-off

SOP 1.7. Power switch before take off

1. Keep GPU power up to 5 min before starting of the engines
2. Check power on GPU (must be lower than 25 Amp)
3. Request pilots to switch on Survey Power
4. Set battery switch to "AC" (check if green led indicator is on)
5. Disconnect power cable of GPU
6. Disconnect cabling from GPU to Battery
7. Check if external sniffer battery takes-over power supply without interruption

2.5. Mission preparation after engine start

After the starting up of the engines, but (optimally) before take-off the final preparations need to be performed to be able to check for eventual malfunctioning. This can be done during taxiing

SOP 1.8. Mission startup.

1. Check power, this can be confirmed by checking the EPS light on the console, in case the survey power is online this light should be white.
2. Start-up console and enter "Mission login" information
3. Start VM on console (GUI>>Control >>FLIRA615) (see)
4. Disconnect VGA converter (VM toolbar Devices>>USB>> Magic Air>>Disconnect USB Device) (see)
5. Reconnect VGA converter (VM toolbar Devices>>USB>> Magic Air>>Connect USB Device)
6. Activate extended view (In Windows XP Task bar>> right click orange symbol>>select extended view) (see)
7. Open DVR video signal one (GUI>>DVR>>Matrix click on the block under video 1) a new black window will be opened (see)
8. Check with Pilots if Video 2 is selected on the Avalex cockpit display
9. Open "AIS-Present" on VM
10. Switch to SNF, zoom in on chart and activate Y-bar scale
11. Restore the AIS present window
12. Move the AIS-present window right (should become visible on the DVR window)
13. Maximize AIS-present (right click on window and select maximize)
14. Open Teamviewer V12, connect to MUMM_LOG_PC (IP: 192.168.1.9, pwd: "mumm")
15. Adjust the AIS present on the MUMM_LOG_PC to optimize the map for the pilots
16. All other aspects of the general flight preparation on the console can now be committed
    a. Enter Flight routing
    b. Enter weather information
    c. Enter mission times in Time Manager
    d. Adjust ECS (activate AIS track and vector)
    e. Open the event manager
    f. Open the AIS info window

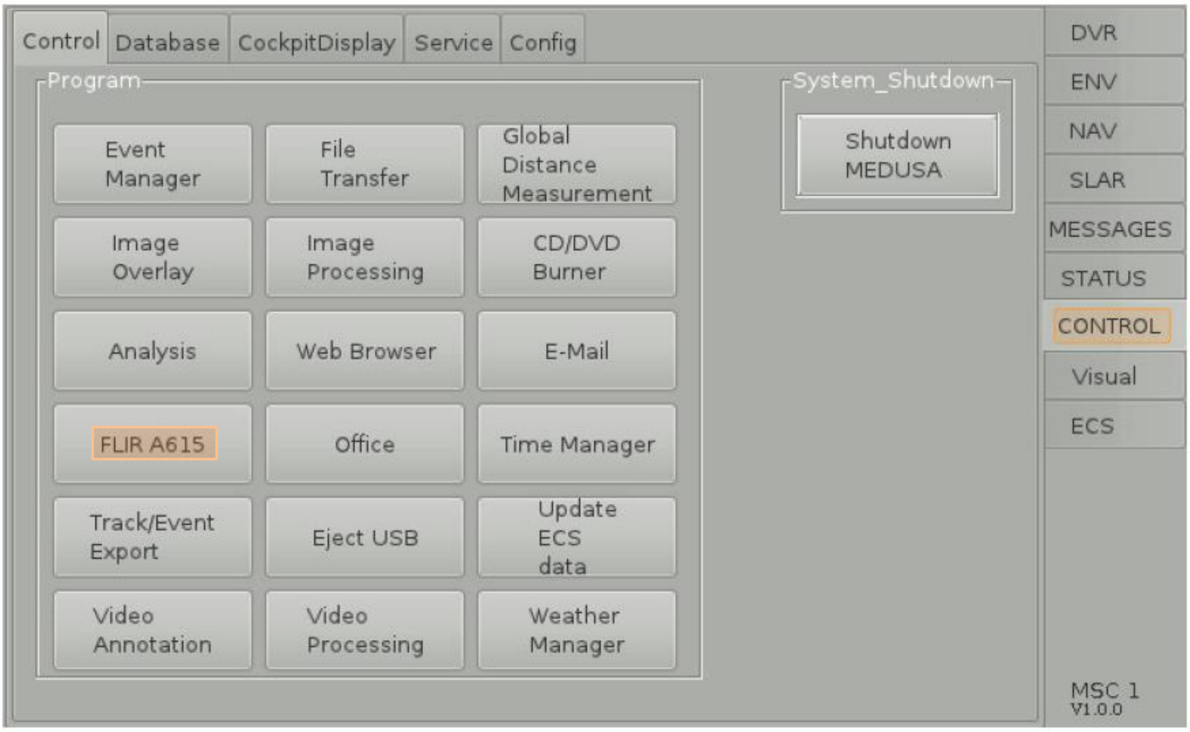


Figure 17 GUI window to launch VM

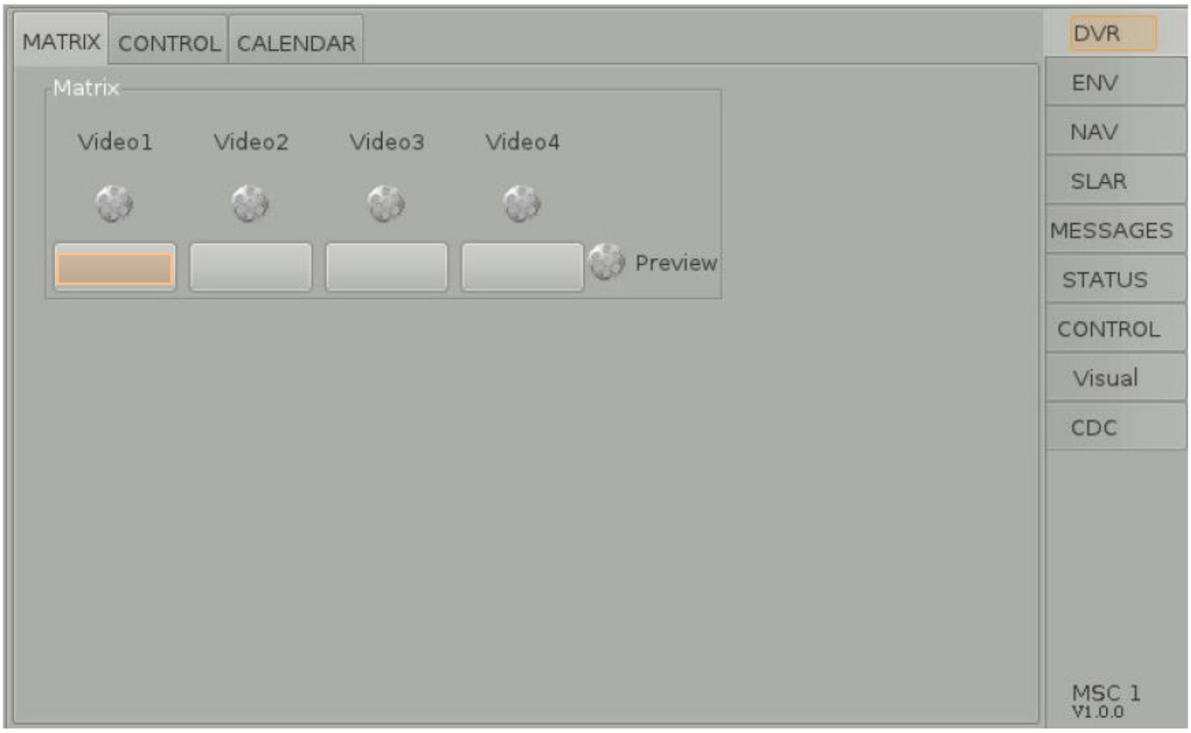


Figure 18 GUI window to activate the DVR window

CHAPTER 3. IN-FLIGHT OPERATION

To optimally conduct sniffer flights the flights needs to be performed by 2 pilots and 2 operators. The whole crew will need to work closely together during flight and a proper and efficient communication protocol needs to be established for this purpose .

3.1. Flight Approach

The monitoring of ship plumes with a sniffer sensor is not without risk and a well-considered flight approach is recommendable. For fixed-wing aircraft with sniffer sensors, 5 different scenarios for flight approaches can be defined according to the wind vector (Vw = direction and force) and the ship vector (Vs = course and speed).

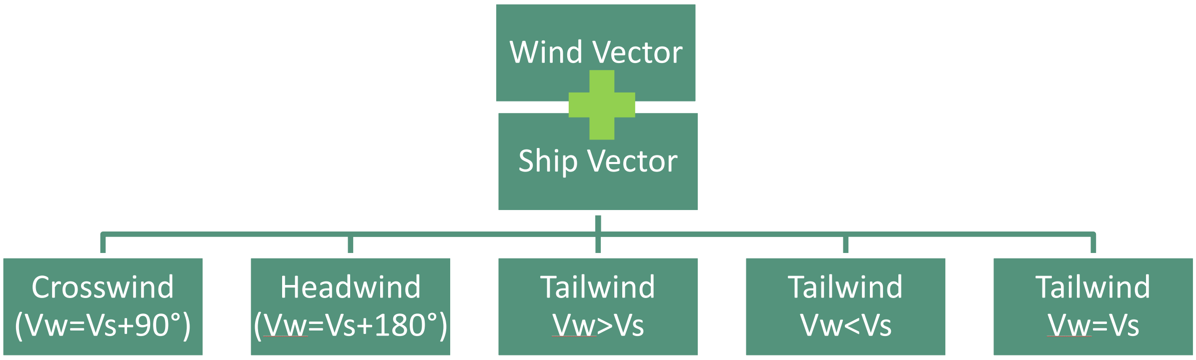


Figure 19 Flight pattern: 5 scenarios

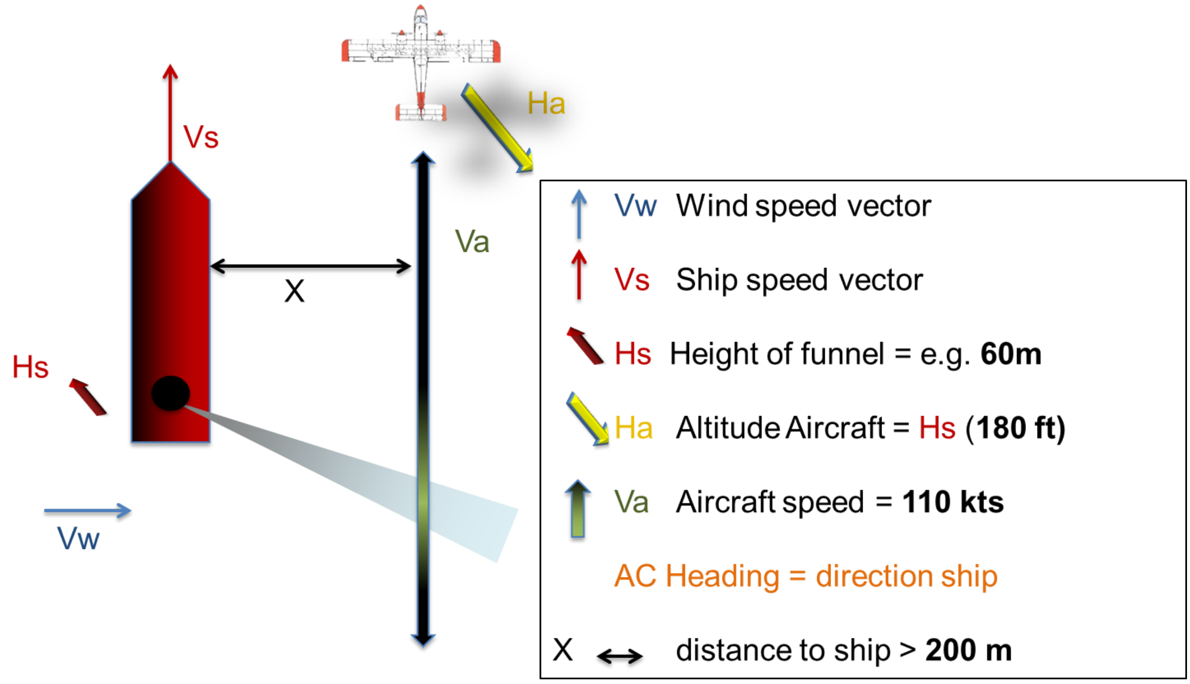


Figure 20 Crosswind Scenario (Vw = Vs +90°)

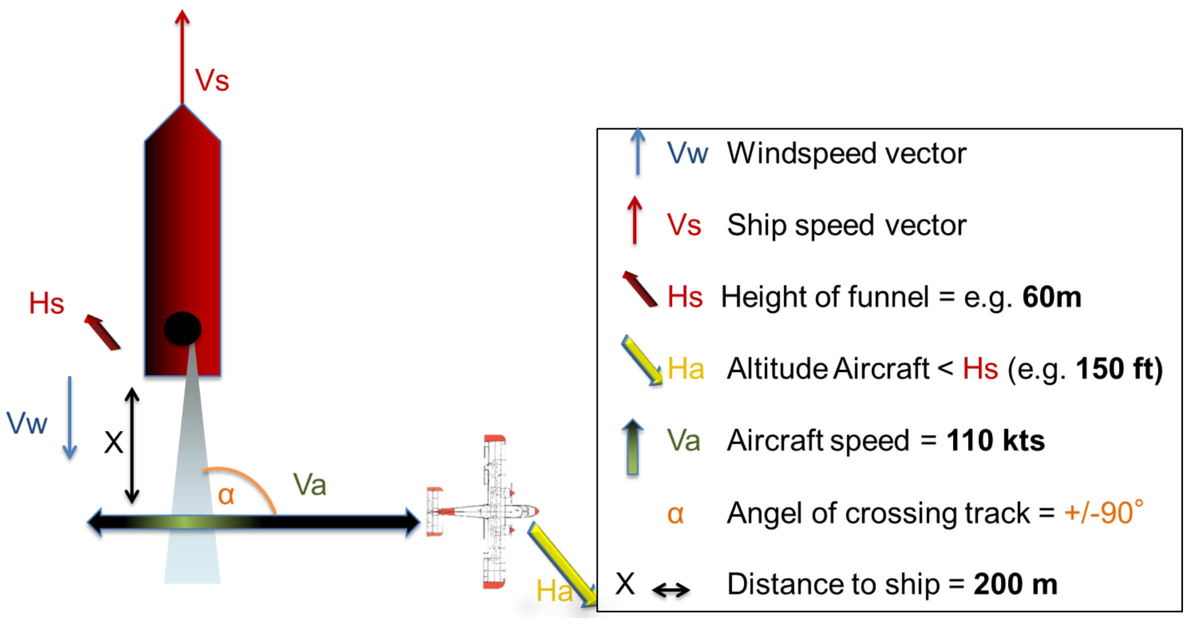


Figure 21 Headwind Scenario (Vw = Vs + 180°)

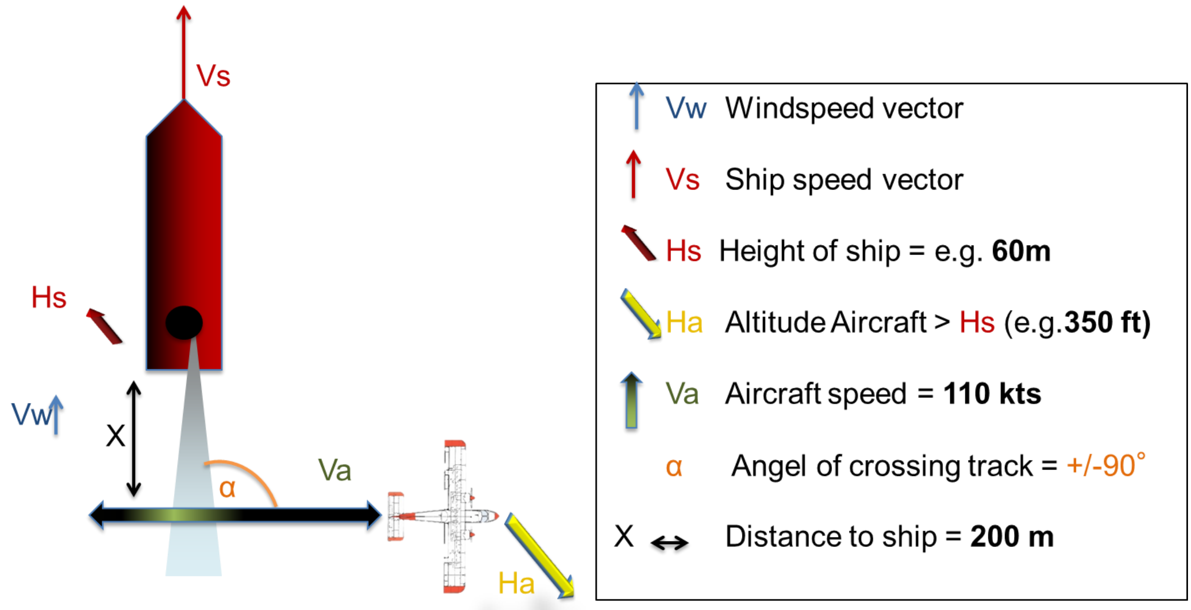


Figure 22 Limited tailwind Scenario (Vw<Vs)

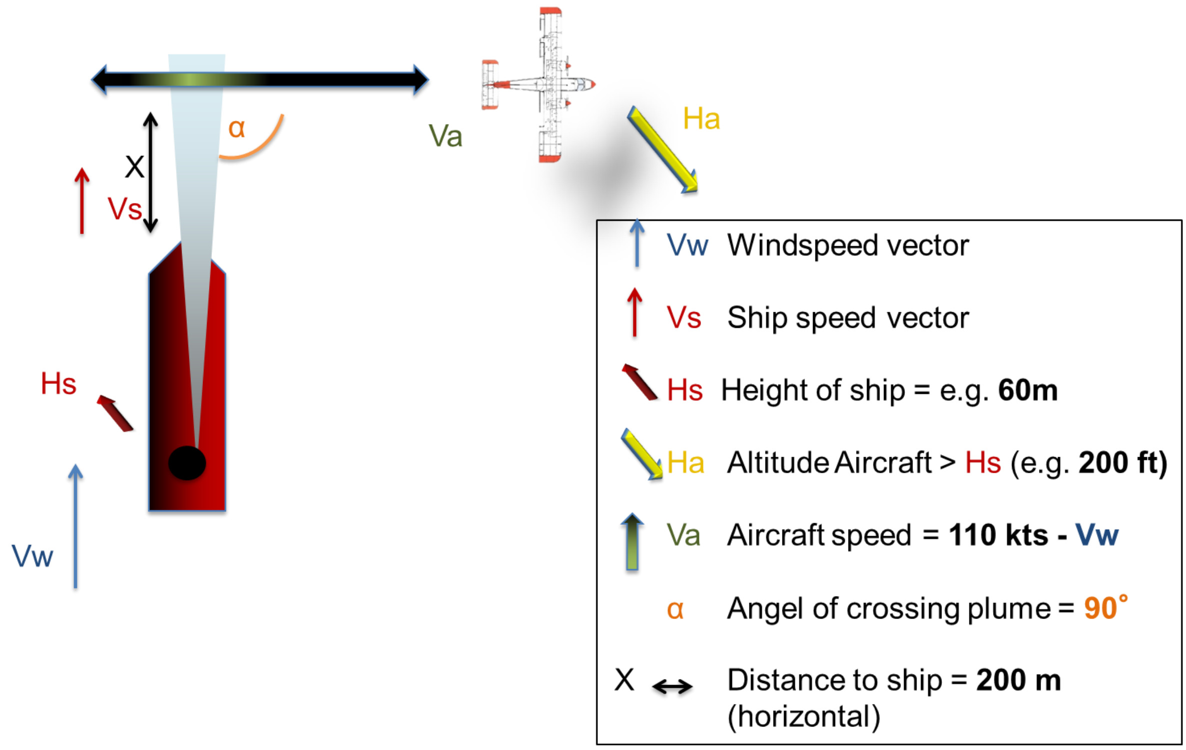


Figure 23 Strong tailwind Scenario (VS<VW)

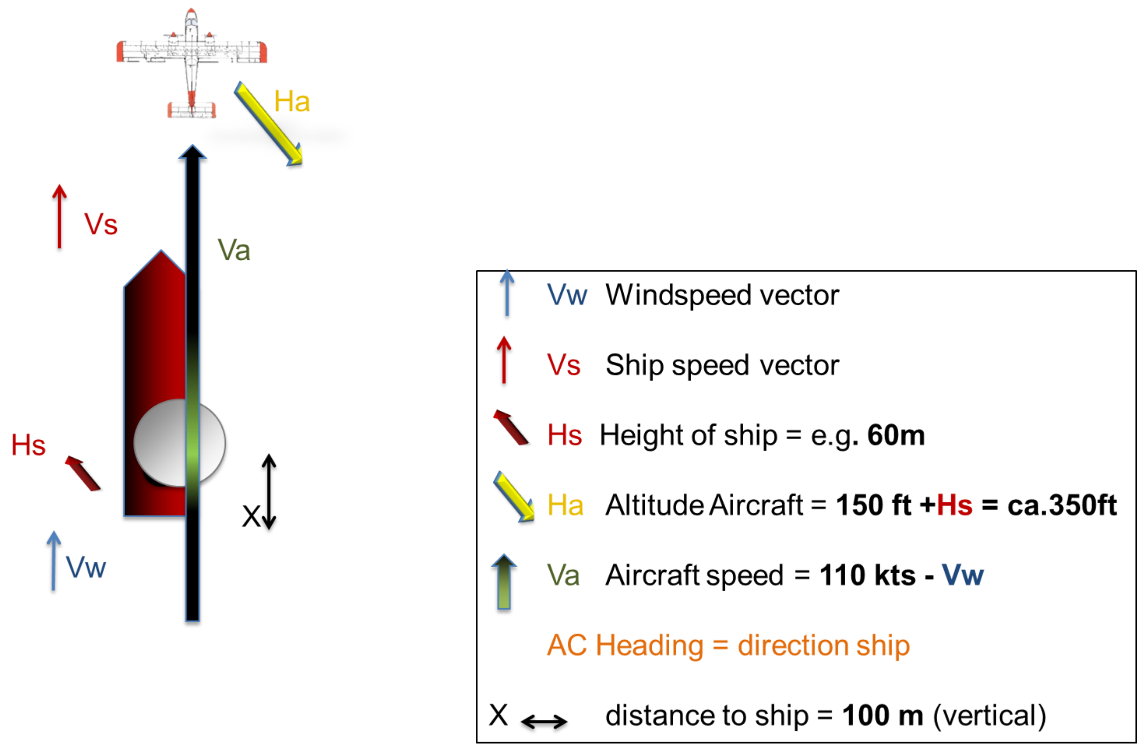


Figure 24 Vertical plume scenario (Vw=Vs)

The main principle is that the exhaust plume is sampled in a straight line with a heading never directly towards the ship, against the apparent wind direction with an angle of ca. 90° relative to the direction of the exhaust plume. Depending on the angle of the wind, the plume may be found higher or lower than the funnel height. In 4 out 5 scenarios the plume is sampled downward wind (wind will move the aircraft away from the ship), only in case of a soft tailwind, the wind may be blowing the aircraft towards the ship but at negligible force (<10 kts). To optimally plan the approach, it is important that the pilots have a good understanding on the location of the plume, therefore the use of well-developed navigation software and communication with the pilots is vital (see 3.5).

In 4 out of 5 scenarios, the aircraft never has to fly directly over the ship. Only in the (rare) scenario with tailwind where Vw = Vs giving a vertical smoke plume, the aircraft has to fly over the ship. In all other cases, a minimum distance of 200m from the ships is recommended.

3.1.1 Altitude

For safety reasons a minimum altitude of 150ft is recommended for MARPOL Annex VI monitoring For the time between sniffer measurements it is advised to fly at 500ft (or more, depending on the time between 2 measurements) for safety reasons and communication with air traffic control authorities.

3.1.2 Distance to ships

For safety reasons, the ship plumes should not be monitored closer than 150m from the ship with fixed-wing aircraft with sniffer sensor, the maximum distance that an efficient measurement can be executed is ca. 2000m but this is strongly depending on the prevailing wind conditions, the ship characteristics and the exhaust plume.

3.1.3 Speed

The recommended indicated air speed (IAS) to execute sniffer measurements is 100–120 kts. The stall speed of the Belgian coast guard aircraft is 35 kts, but for sniffer flights the operational speed is 110 kts with engine power settings of 59%.

3.1.4 Plume localisation

The localisation of a ship's exhaust plume can sometimes be challenging, even with (2D) software models and an experienced aircrew. The current IGPS Real software is providing the estimated direction of the exhaust plume and is able to visualize the plume location on a nautical chart together with the AIS information. The software is not able to estimate the height of the centre of the plume. As a result several measurement attempts might be required before a successful measurement can be made.

In case there is no visual indication of the height of the plume, it is recommended to do the first measurement at funnel height, if needed followed by a second and/or third measurement attempt which can be done 25-50 ft higher or lower than the funnel height. Depending on the wind conditions it might be necessary to make a full 360° turn (in case of strong wind) or only a 180° turn (in case of moderate wind) for a consecutive measurement attempt. The information of the relative plume height (compared to the funnel) can be used for following measurements for ships with same heading and speed.

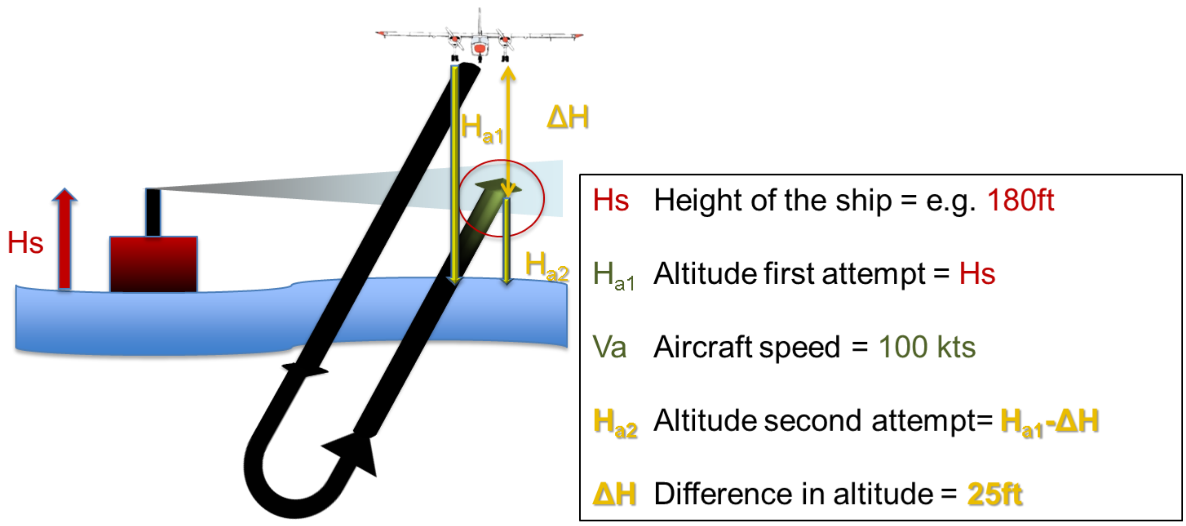


Figure 25 Sampling procedure in case the first attempt was not successful (low to moderate wind conditions).

3.2. Console operator

The console operator is responsible for the following tasks in flight:

- Selecting the ships for inspection (3.2.1)
- Communicating the position and the smoke plume location to the pilots (3.2.2)
- Evaluate measurement quality (3.2.3)
- setting the mode of the NOx sensor (3.2.4)
- conducting the radio communication (for NOx) (3.2.5, **Annex C** - Radio communication checklist),
- taking notes (FSC, NOx, Number of attempts and engine parameters)
- creating the reports of non-compliant ships (Reporting to PSC).

3.2.1 Ship selection

The main purpose of airborne MARPOL Annex VI monitoring is currently still on the effective targeting of ships for port state inspection, and therefore as many different ships as possible must be monitored at sea at various locations. Some limitations apply:

- Only ships en-route should be monitored
- Only ships with length larger than 100m should be monitored, this differs according to the wind conditions and ship type, in most conditions a minimum of 130m is more adequate

In case certain ships or companies are repeatedly observed to be non-compliant, these ships or companies can be inspected priory. On the other hand, if certain ships are repeatedly observed to be compliant, these ships can sometime be skipped to reduce flight time (see Figure 26).

SOP 1.9. To select a ship for inspection

1. make sure that “only moving” ships is enabled
    a. Go to MAP (a)
    b. Select settings tab in bottom right (h)
    c. Activate “only moving ships”
    d. Ships are displayed according to size (d)
2. Move with the cursor over the different ships, AIS info is displayed in top left corner, to select useful ships
    a. Look at the size (>100m)
    b. Look at the speed (slow moving ships are still displayed but should not be selected)
    c. Look at the age to identify Tier
3. Double click on ship (will get a red circle)
4. When other users select ships, the ships will get a magenta circle

LNG ships

Gas tankers running on boil off gasses emit almost no SO2, these ships can be monitored although the often generate zero or even negative FSC values. However some gas tankers have permission to use high sulphur fuel oil for emergency purposes, this should be evaluated by the PSC inspector.

EGCS or scrubber ships

Ships equipped with emission abating methods (Exhaust Gas Cleaning Systems or scrubbers) are running on high sulphur fuel oil, but the exhaust gasses are threaded resulting in emissions with lower SO2/CO2 ratio (calculated FSC) than regular 0.1% LSFO ships. Scrubber ships should be inspected regularly to evaluate the proper working of the scrubber system.

3.2.2 Communication with pilots

When ships are selected they are visible to the pilots on the MAP 2 screen. The zoom levels needs to be set by the operators (this can be done by connecting to the MUMM-PC using TeamViewer). Once the ships are selected, the operator decides which ship to inspect first. The compass (b) together with the white heading line (c) is used to give the heading to the next ship, the distance spheres (g) give the relative flight time (1,2,5,10min). For the selected ships, the software will provide an indication of the smoke plume position relative to the ship (f) using the 12hr direction system this position can be shared quickly to the pilots. Following information should be provided to the (co)pilot:

- Heading to the next ship (b+c): in English xxx° (pronounce all digits individually)
- Time to the next ship (g): x min
- Position of the smoke plume (f): xx o'clock
- E.g.: Target at three zero zero; 1 minute; smoke at three o'clock

When getting closer to the next target should be provided so that pilots can orientate and optimize the flight pattern. When the ship is measured the graphs will show this to the pilot (Video 2) and the console operator (DVR-1) when the measurement is successful this should be communicated.

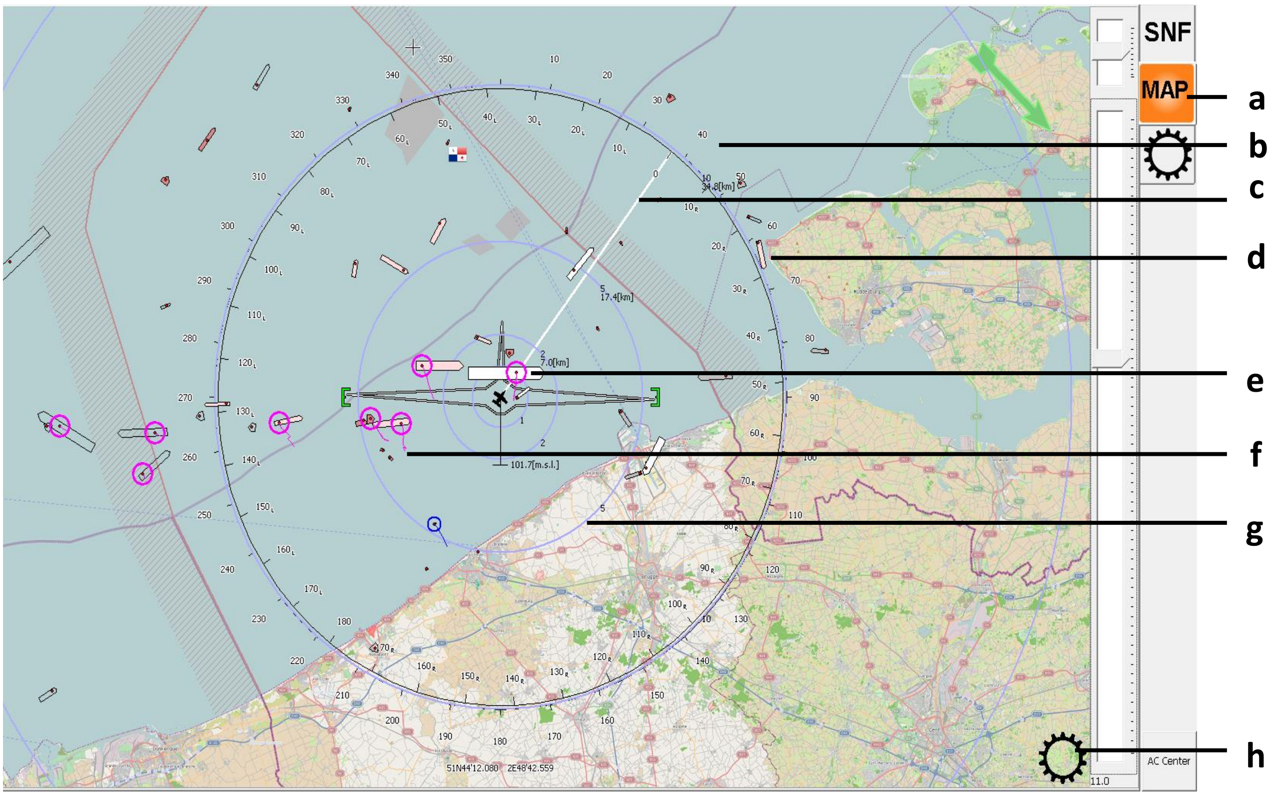


Figure 26 MAP view of IGPS software

3.2.3 Measurement Quality

Both operators should asses the quality of the measurements, in most cases a quick glance at the graph on the DVR-1 graph is sufficient to establish if the quality is enough, in case of doubt the quality should be checked by the laptop operator. Following conditions must be met:

- Stable background before and after the peak
- Sufficient peak height compared to background noise (min 5 ppm CO2)
- Sufficient time between peaks
- Good singular peaks and no interference from other ships or other sources

In case the measurement quality is not good enough, a second measurement should be performed.

3.2.4 NOx sensor mode

In case a too high FSC is observed during (one of the) first attempt(s) (10% of the cases). The NOx sensor should be set to NO and 2 measurement confirmation should be performed.

SOP 1.10. Switching to NO after FSC alert

1. Set the sensor to “NO mode”
    a. Quick menu
    b. Gas to measure
    c. Set to “NO”
2. Take 2 more measurements
3. Set the sensor back to “NOx mode”
    a. Quick menu
    b. Gas to measure
    c. Set to “NOx”

3.2.5 Radio communication to get SFC (NOx alerts)

For ships outside the piloted areas. In case an initial measurement shows a potential violation, contact should be made with the ship (CH 16→67), using the special radio communication checklist from (see **Annex C - Radio communication checklist)**, to request engine parameters that laptop operator will use to calculated the SFC. Following information must be requested from the chief engineer:

- Fuel consumption main engines(s) (m^3/hr)
- Current power of the main engine(s) (kW)
- Total power of the main engine(s) (kW)
- Maximum RPM of main engine(s)

3.2.6 Sampling attempts

Monitoring campaigns have shown that most vessels are compliant (estimate of 90-95% based on BE and SE monitoring results), and therefore in many cases 1 FSC measurement (= 1 low pass for fixed-wing aircraft with sniffer sensor) per vessel will be sufficient to verify compliancy, in most cases (80%) the first measurement attempt is successful. As mentioned above however, it may sometimes be required to perform several additional measurement attempts before a successful FSC measurement can be made. To limit the flight safety risks and optimise the aerial monitoring efficiency it is recommended to limit the number of measurement attempts. In case a first measurement attempt is unsuccessful it is recommended to perform not more than 2 additional attempts, after which the ship should be abandoned.

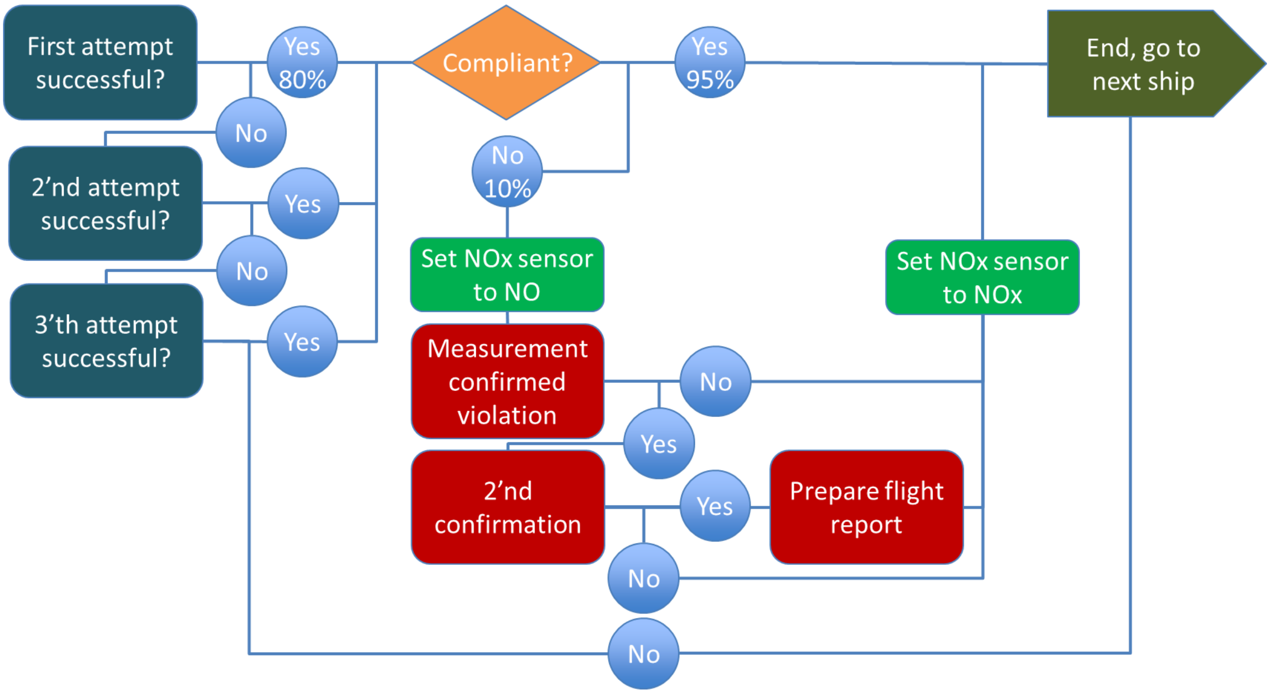


Figure 27 Schematic overview sampling attempts for fixed-wing aircraft with sniffer sensor for FSC monitoring.

3.2.7 Taking notes

The laptop operator should write down following information:

- time and end of sniffer mission type,
- name of the ship,
- measurement results (FSC+NOx),
- number of measurements,
- engine parameters.

3.3. Laptop operator

The laptop operator is responsible for conducting the measurements and in case of radio communication to enter the engine parameters in the SFC calculation file. In case a non-compliant ship is observed, the console operator will create the report and in the meanwhile the laptop operator may take over the guiding of the pilots to allow the console operator to collect the data for the reporting (3.2.1 and 3.2.2).

3.3.1 Conducting measurements

The laptop operator works mainly in the SNF mode, by sliding the zoom level (top) to the right the peaks are optimally visualised. To enable the scale click on the “CO2”, “SO2”, “NOx” legend (left side). When flying through the plumes the concentrations will give peaks on the chart. To conduct a measurement:

SOP 1.11. To conduct measurements

1. Click on the CO2 graph in the area of the peak

2. A second view opens, this is the plume measurement window
3. Move the red box start and end in line with the start and end of the peak
4. Move the left line of the first black arched box “start” to a stable area in front of the peak
5. Move the right line of the second black arched box “end” to a stable area behind the peak
6. The measurement of FSC and NOx is displayed in the top together with the Keel Laying Year and possible source
7. Click on “ok”
8. MAP view will be opened automatically
9. Assign ship
    a. go to the source (ship) with cursor,
    b. click right,
    c. Select “use xxx ship xxx…”
10. Mark ship
    a. go to ship with cursor
    b. click right and select either “HIGH”, “LOW” or “NOT DETECTED”
11. Set map back with “AC centre” (bottom right side)

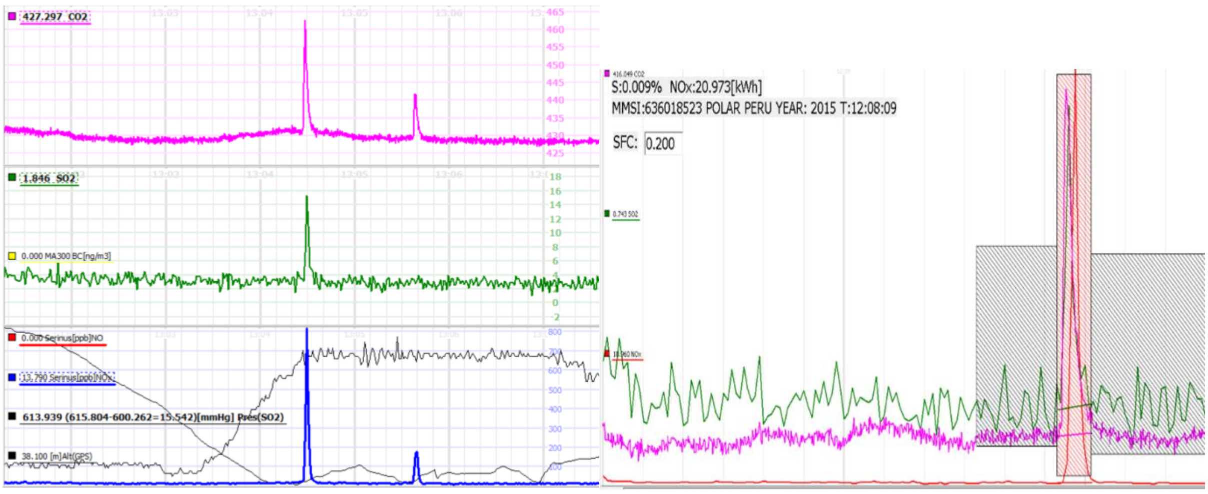


Figure 28 Figure 27 SNF view with the basic graphs on the left side (CO2, SO2 and NOx) and the plume measurement window on the right side

The laptop operator should also check if the measurement quality is sufficient (3.2.3), special attention should be given to non-compliant ships.

- **Min 5ppm CO2** (for compliant ships)
- **Min 3ppb SO2** (for non-compliant ships)
- **Min 15ppb NOx** (for non-compliant ships)
- **Stable background before and after passage** (no inversion layers)
- **No SO2 tail** (cut off at CO2 peak)
- **No other plume peaks** (from ships or land) **within 30 sec before or after measurement**

3.3.2 NOx

For the compliance monitoring of NOx, the laptop operator should look at the following information prior to the measurement:

- Keel laying date (IGPS)
- Ship type (visual)
- Ship length (AIS)
- Ship speed (AIS)
- Ship location

The thresholds for reporting will depend on this information.

Keel laying date

Different thresholds were defined based on the keel laying date. The dates is displayed on the AIS info box when selecting a ship on the IGPS MAP. Tier I starts from 2000, Tier II from 2011 and Tier III from 2021 (Table 3).

Ship type

The thresholds for ships with RPM>500 rpm should be used (Table 4) for following ship types: ROROs, Passenger vessels, cruise ships.

Ship length

For ships <160 m the threshold for ships with ERS > 500 rpm need to be used for the initial evaluation (Table 4).

Ship speed

For containers and tankers possible violation should only be reported from the orange flag when their speed is <12 kts. Roros and bulk carriers sailing slower than 8 kts should only be reported from the orange flag (Table 4).

Ship location

In case the ship is close to port (Westerscheld, Zeebrugge), the vessel has a pilot on board and is most likely in communication with VTS, therefore no VHF radio-communication should be established. For these ships an SFC of 160 g/kWh will be used. There is no need to adjust the SFC in the software. In case a potential violation is observed with the standard SFC of 200g/kWh, the measurement should be recalculated using the “Threholds, Bias and SFC.xls” file (sheet NOX→SFC correction) if with the lower SFC the ship is still in violation one additional measurement should be taken.

3.3.3 Colour flags (thresholds) FSC

FSC measurement can be categorized according to a threshold or colour flags based on the FSC value, the measurement-uncertainty and level of quality. The colour flags can always be consulted in flight in the “Threholds, Bias and SFC.xls” file (sheet FSC).

Table 2. Threshold colour flags for categorizing the emission measurement and reporting to PSC

Thresholds	FSC	CI
Yellow	0.13	68%

Orange	0.2	95%
Red	0.3	99%

3.3.4 Colour flag (thresholds) NOx

The thresholds for NOx are much more complex than for FSC, for NOx, 2 tables with colour flags are composed, the first set is for ships with an RPM smaller than 500 and is based on the limit for an RPM < 130 (Table 3), the second set is for ships with an RPM > 500 (Table 4).

In addition to the RPM also the Keel Laying date (Tier) will determine the threshold, a colour flag list is provided for every Tier level. The values are based on the uncertainty and a confidence level. The values are rounded to provide more operational values that can be easily memories by the operators. Both tables are also available in “Threholds, Bias and SFC.xls” file (sheet NOx) and should be consulted when in doubt.

Table 3 Threholds for ships with RPM <500

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (≥2021)	Tier I+II	Tier III	CI
Limit (130xRPM)	17	14.4	3.4	NTE (BE)	NTE (IMO)	
Yellow	25	20	7	15%	50%	68%
Orange	35	30	9	20%	60%	95%
Red	55	45	12	50%	65%	99%

Table 4 Thresholds for ships with RPM >500

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (≥2021)	Tier I+II	Tier III	CI
Limit (500xRPM)	13	10.5	2.6	NTE (BE)	NTE (IMO)	
Yellow	20	15	5	10%	50%	68%
Orange	25	20	6	20%	50%	95%
Red	45	35	7	50%	50%	99%

3.3.5 SFC

When a potential NOx violation is observed the console operator will perform radio communication with the ship to obtain following engine parameters:

- Fuel consumption main engine (m^3/hr)
- Current power of the main engine (kW)

- Total power of the main engine (kW)
- Maximum RPM

The parameters A-C can be entered in the "NOx" sheet (Figure 29). The SFC is calculated automatically. This SFC can be entered in the IGPS to conduct a second measurement.

SOP 1.12. Change SFC valued on IGPS

1. Click on the CO2 graph in the SNF window
2. The plume measurement window will be opened
3. The SFC values is indicated in the left side of the window
4. Enter the new value for SFC
5. Double left mouse click to finish
6. The next measurements will be taken with the new FSC

As in most occasions the engine parameters will be received after the second measurement was taken, the NOx measurements can also be converted using the sheet "NOX→ SFC correction". The SFC is already updated based on the entered data in the NOx sheet, the two first measurements only need to be entered to get the converted NOx values.

3.3.6 Engine load

The engine load is calculated together with the SFC in the NOx sheet when the engine parameters are entered. Ships sailing at an engine load less than 25% (rounded to 5%) should be reported from the orange colour flag only and should be reported as "off cycle"

SFC calculation		
SFOC	Fill in data below	kg/kWh
Fuel consumption	Fill in data below	kg/hr
Fuel Density	Default of 0.9 is used	
Current power use	Fill in data below	kWh

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (>2021)	Tier I+II	Tier III	CI
Limit (130xRPM)	17	14.4	3.4	NTE (BE)	NTE (IMO)	
Yellow	25	20	7	15%	50%	68%
Orange	35	30	9	20%	60%	95%
Red	55	45	12	50%	65%	99%

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (>2021)	Tier I+II	Tier III	CI
Limit (500xRPM)	13	10.5	2.6	NTE (BE)	NTE (IMO)	
Yellow	20	15	5	10%	50%	68%
Orange	25	20	6	20%	50%	95%
Red	45	35	7	50%	50%	99%

Threshold = Limit.NTE + σ.U + b

Fill in fuel effieciency data in this table		
Fuel Consumption (main engine) *(choose one of the following parameters)*		*Example*
kg/hr		*7500*
m³ / hr		*7.5*
m³ / Day		*180*
l/hr		*8000*
cubic ton/hr		*8*
cubic ton/day		*200*
Density (0.8-1 kg/l) *(choose one of the following parameters, if left empty default of 0.9 will be used)*		
kg/l		*0.98*
kg/cubic ton		*980*
Power use (main engine) *(choose one of the following parameters, when using parameters in red, both parameters need to be provided)*		
kW		*37500*
mW		*37.5*
engine capcity (kWh)		*50000*
engine load (%)		*75*

Figure 29 SFC calculation with the Thresholds and Bias Excel file (NOx sheet)

CHAPTER 4. POST-FLIGHT MISSION OPERATION

To avoid time loss and issues with the power supply the post flight operations must be briefly discussed between operators and pilots before the shutdown of the engines and survey power supply. The operations after flight include the reporting, import of mission data and ground powering or shutdown of the sniffer system. The different post flight operation do not necessarily have to be committed successively but can be initiated on the same time by different operators/pilots.

4.1. Reporting to PSC

The sniffer measurement results of non-compliant vessels have to be reported to PSC and the vessels will then be marked in the Thetis-EU database. Therefore the aerial monitoring results on non-compliant vessels should be reported in near real time. For a non-compliant vessel, this means that reporting time is limited to 15 min after landing in order to provide sufficient time for the planning and prioritisation of port inspections. The flight report is send to the national 24/7 coastguard station (MIK), who forwards the flight report to PSC. Measurement results of both non-compliant as compliant vessels are also shared throughout Thetis-EU, this data-export and upload process is largely automated, but some data still needs to be validated manually.

Table 2 PSC-Communication matrix

	Compliant	Non Compliance
Reporting Time	<1hr after flight	Near real time (<15 min after landing)
Reporting Means	Thetis-EU web database	Thetis-EU + Flight report

See Section 3 of the Sniffer Quality Management System, Chapter 4 for more information on the reporting of non-compliant ships using the Belgian Flight Report.

4.2. Import of ship monitoring data

After all sniffer measurements are done, but **before the sniffer is shut down** the emission file and log files from the MUMM LOG PC need to be backed-up by the laptop operator:

SOP 1.13. To backup TCP log files

1. Copy logs
   a. On laptop go to MUMM-LOG-PC on TeamViewer
   b. Go to C:/IGPS/TCP LOG
   c. Copy recent TCP logfiles (from same day)
   d. On Laptop go to seafile folder 0.QMS\Sniffer DM\Logs\YEAR
   e. Paste the files, in case error message pops up, select “Don’t copy” + “do this for all other x files”
2. Copy the emission file
   a. On laptop go to MUMM-LOG-PC on TeamViewer
   b. Go to C:/IGPS
   c. Copy Emissionsdata_MUMM_LOG_PC.txt
   d. On laptop go to C:/IGPS/

  e. Paste the emission file, select "replace"

Once the date is backed up, all IGPS data needs to be imported via following procedure.

SOP 1.14. Import IGPS data

1. Open personal file "IMPORTV22_operatorinitials.xlsm" in "Seafile >> 11-Instrumentatie >> 05-Fluxsense_Sniffer >> SNIFFER DATA >> IMPORT IGPS DATA
2. Import the raw data
   a. The first button will import all data from the C:\IGPS directory
   b. The second button will allow you to import data from a dedicated directory (eg. IGPS POST FLIGHT)
3. Click third button "Calculate Results", the Results sheet will be opened,
4. Check if all ships are present
   a. If all ships are present continue with 5
   b. (if not close import and add measurements, see 5.2 and restart at 1)
5. Edit data in Results sheet
6. Delete double lines
7. Add the number of attempts
8. Check for unknown Keel Laying Years (e.g. use Thetis-EU or Marine traffic);
9. Check the colour flags for FSC
   a. Check if the sequence is correct for NO/NOx
   b. Check the sequence of the emissions measurements
   c. In case a ship has 2 different colour flags use lowest flag
   d. Ungroup the columns right from the emission measurement (blue numbers) change from 1,2,3 to 2,1,3 or accordingly
10. Check the colour flags for NOx
   a. Check the Gross Tonnage for TIER 0 ships with length <150m
   b. check the sequence of the emissions measurements, in case a ship has 2 different colour flags use lowest flag
   c. Ungroup the columns right from the emission measurement (blue numbers) change from 1,2,3 to 2,1,3 or accordingly
11. Recalculate sheet, and check if all adjustments are made correctly
12. Go back to "guidelines" and add start date (if different from the present day) add start/end times in case of multiple flights
13. Add flight number
14. Click apply filter
15. Check the Full data, ILT and EMSA sheets (sheets are read only)
16. Click on all 3 Export buttons
   a. Full data will be exported in the standard YEAR directory,
   b. ILT sheet will be exported in the EXTERN directory
   c. The EMSA file will be exported in the EMSA input files data directory)

Note: For violations check if after 15 min the EMSA file is moved from the "input files" directory to the "imported" directory and the alert is available on Thetis-EU,

In case of errors, or for more information on login in to Thetis-EU follow the steps as described in Section 3 of the SQMS, Chapter 5.

4.3. System shut down with power on sniffer (see SOP 1.2)

SOP 1.15. Shutting down with power to sniffer

1. At tarmac in EBOS: GPU, cable and cable protector are in the orange box (code: 213)
2. Guide cable through camera opening (use dedicated connector to split the cable from the reel)
3. Connect GPU to external AC power bus with dedicated cable (see Figure 13)
4. Plug in GPU to reel
5. Plug in the power extension cable to the 230V socket (on the lighting pole)
6. Switch on sniffer battery must be in “EXT” position

4.4. System full shut down

SOP 1.16. Full shut downs

1. Shut down sniffer sensor on the VM by First operator:
    a. Go to the utilities tab
    b. Press the power button in the right bottom
2. MUMM-LOG PC will shut down, together with the IGPS software on the VM.
3. After IGPS software is off, switch off sniffer switch at intercom jacks
4. Put Sniffer battery switch in off mode (middle)
5. Set carbon filter to ground

CHAPTER 5. POST FLIGHT ANALYSIS

This chapter describes the re-analysis of mission data for operational purposes, this can be done at any time after the flight. For more detailed data analysis see Section 3 of the Sniffer Quality Management System, Sniffer Data Management Manual, Chapter 5.

5.1. Copy TCP-log files

Make a backup of the program files, log files and emission files from the IGPS folder from the LOG_PC (see Chapter 4)

5.2. Reloading mission using IGPS-Present

IGPS present can be used to reload old mission data (from log files), a special IGPS Post flight folder has been installed on the C:\ and shared through Seafile, this contains the same software and folders as the IGPS folder, but the advantage is that the data may be deleted.

SOP 1.17. To reload mission

1. Copy Emissiondata_ODN_XXX.rbins.be.txt from C:\IGPS to C:\IGPS POST FLIGHT folder
2. Open IGPS POST FLIGHT and open LOG file (SNF>>Setting>>load data file>>Select LOG with flight hour)
3. Flight will be loaded (slow) to go faster to the correct time click on the SNF graph (look at timer)
4. When time is right, go to MAP to identify ship and when AC passes through ship plume go to SNF
5. Do measurement and assign measurement to correct ship
6. Data is now added to the emission data under the IGPS post flight folder and be either copied back to the IGPS folder or can be imported from the IGPS Post flight folder in the Import.xls file

5.2.1 Missing Data

In case ships are missing from the import file or in case the ships are present but the measurements are missing, the import needs to be ceased and the data needs to be extracted first by reloading the missing, For more information on how to retrieve this information see Section 3 of the Sniffer Quality Management System, Sniffer Data Management Manual, Chapter 5.

5.3. Detailed analysis of mission data with IGPS extract and IGPS analysis

SOP 1.18. Analysis with IGPS ANA

1. Open IGPS Extract (AIS_Ex8)
2. Press start
3. Select log file (from Sniffer_Data/Logs)
4. Select Temp folder, this folder will be used as temporary working folder
5. After extraction is completed, close AIS_Ex8
6. Open IGPS_Ana44
7. Press start

8. Select Temp Folder
9. Select emission file (C/IGPS/Emsissiondata_ODN-name)
10. Use green arrows to scroll in flight to look for the required peak/ship
11. Adjust background and peak brackets where necessary
12. Go to map, Right mouse click, link to ship
13. Save (the Emissiondata file will be updated)

For more information on IGPS EXTR and IGPS Ana see Section 3 of the Sniffer Quality Management System, Sniffer Data Management Manual, Chapter 1.

CHAPTER 6. REFERENCES

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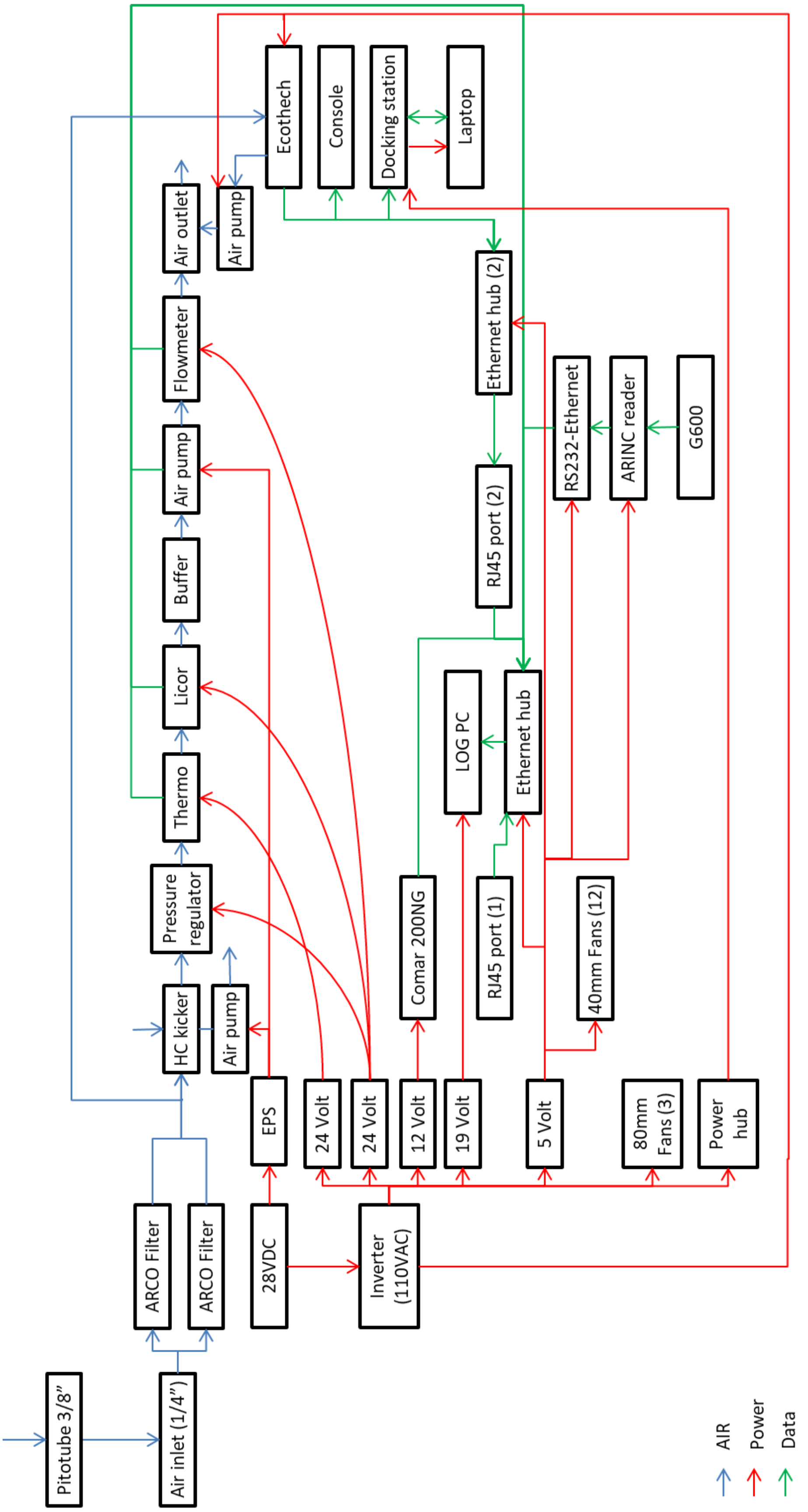
ANNEX A – TECHNICAL FICHE OO-MMM

1. Airborne platform	
Type	Britten Norman Islander
Call sign	OO-MMM
Length	10.9
Wingspan	14.02m
Height	3.77m
Engines	2 Lycoming engines (300 hp)
Autonomy	5 hrs
2. SLAR	
Model	Terma SLAR 9000
Range	20/20 nm (standard operations) up to 40/40 nm
Resolution on ground	35m (20nm range); 75m (40 nm range)
Note:	With pixel per pixel georeferencing from Flight Management System (FMS)
3. IR sensor	
Model	FLIR A645
Resolution	650x480
FOV	45°
F-value	1
Thermal sensitivity	50 mK
4. Video camcorder	
Model	Sony FDR-FX7
Resolution	1080i
Focal length	37,4 -748 mm (16/9) 45,7-914mm (4/3)
Optical zoom	x20
5. GPS Positioning en Flight Management System	
Model GPS	Garmin GTN650 (x2)
Model FMS	Garmin G600
Notes	Data-export of coordinates, course, airspeed, groundspeed, windspeed and direction, time, date, altitude (barometric), roll and pitch angle to control-unit Built in Airband VHF radio-communication 1m accuracy
6. Still camera's	
Model 1	Nikon D850
Lens 1	VR 16-35mm
Model 2	Nikon D800

Lens 2	VR 70-300 mm
Note	Image overlay on console Georeferenced from Garmin 18x PC GPS receiver
7. Control-unit	
Model	OPTIMARE MEDUSA System
Note	Integration and control van sensors and sensor-images equipped with ECDIS and Comar SLR200 AIS receiver
8. Radar altimeter	
Model	Bendix King KRA405B
Note	Data-export from barometric altitude to control unit Accuracy: 1m
9. VHF/FM Airborne transceiver	
Model	Technisonic TFM-138B
Note	Installed in control unit Voice recording on video images
10. Satcom	
Model	Garmin GSR 56
Note	Control is Integrated in Garmin G600 Flight Management System Voice communication, weather updates and Text messages (SMS)
11.Transponder	
Model	Garmin GTX335 Mode ES
Registration	10036
Transponder n	44B5AD
Serial Nr	C468

ANNEX B - BLOCK DIAGRAM



ANNEX C - RADIO COMMUNICATION CHECKLIST

On channel 16

Shipname- shipename- shipname this is the Belgian coastguard aircraft with call sign

Oscar- Oscar Mike Mike Mike on channel 16. How do you read me Over

Shipname please reading you …by 5, please switch to channel **6-7**. Over

On Channel 67

1. We are conducting air pollution surveillance and I have to inform you that we measured some high NOx values in the smoke plume of your vessel. We would like to ask your chief engineer to provide us with some information, is that ok for you?
2. What is your fuel consumption of your main engine(s) at this moment in **metric ton/hr**?
3. What is the current power use of your main engine(s) in kWh?
4. What is the total power of your main engine(s)
5. What is your maximum RPM

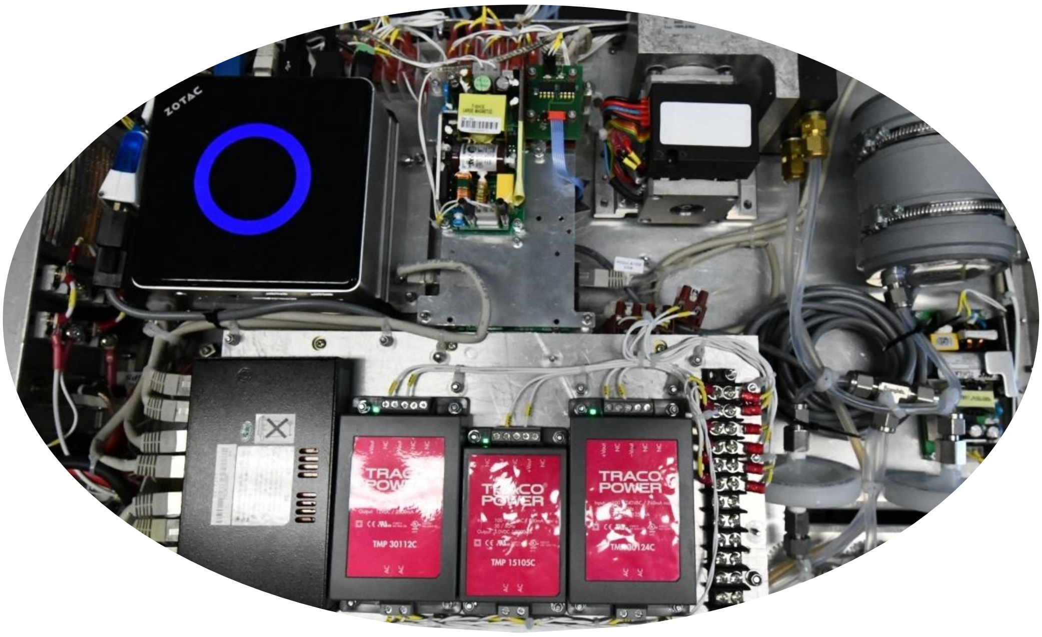
End:

6. Please record in your logbook that we have contacted you.
7. (My initials are …….) if requested!
8. Our call-sign is Oscar - Oscar - Mike - Mike - Mike
9. Thank you for your cooperation sir and good watch, OUT

SNIFFER QUALITY MANAGEMENT SYSTEM

SECTION 2.

SNIFFER QUALITY ASSURANCE MANUAL



REVISIONS

Revision Date	Chapter - section	Page	Description
27/06/2018	Chapter 4 4.2	4-6	Modification of SO2 hardware calibration with J251 connector (option 1)
23/06/2022	All		Adding of NOx sensor, NOx pump, hydrocarbon kicker and update of the air pump
25/07/2022	Chapter 1 and Chapter 6 1.1, 1.1.8, 1.3.3 and 6.1.10		Adding of Hydrocarbon kicker
25/07/2022	Chapter 3 and Chapter 5 5.1, 5.2		Adding of plume simulation mixture

ABOUT THIS MANUAL

The Sniffer Quality Assurance Manual was developed by MUMM to be used with the sniffer installation on board of the Belgian Coastguard Aircraft, a BN Islander (BN2A) with call sign OO-MMM. The Quality Assurance System constitutes to Section 2 of the Sniffer Quality Management System (QMS). The Sniffer Quality Management System was specifically designed for the Belgian Marpol Annex VI monitoring program entailing the proper functioning of the sniffer system on board of the Belgian Coastguard Aircraft and the provision of accurate and consistent data collection. The Quality Management System consists of in total 3 Sections, Section 1 describes the operational aspects of the airborne monitoring. Section 3 consists of the data management aspects (see Figure 1). For every section a detailed manual is developed and available on the Seafile folder 1. SNIFFER QMS under the Seafile library 05-Instrumentation/05-FluxSense_Sniffer

In this manual, detailed information and step to step instructions are provided about the installation, calibration, and servicing of the sniffer sensor system. The manual is organized in different chapters and annexes to provide direct access to specific information, chapters can be toggled directly. The chapter can also be used as stand-alone guides during the different interventions in the field.

- **"Chapter 1 Sniffer sensor "** describes the installation on board of the OO-MMM aircraft and the main components of the Sniffer sensor system.
- **"Chapter 2 Intervention and servicing scheme"** provides a detailed overview and schedule of the required maintenance interventions and preventive service.
- "**Chapter 3 Software calibrations**" provide all information to perform software calibrations.
- "**Chapter 4 Hardware calibrations**" provide all information to perform hardware calibrations.
- "**Chapter 5 Management reference gasses**" describes all practical aspects of the management and calibration of the reference gasses.
- "**Chapter 6 Preventive servicing**" provides detailed maintenance instructions for preventive servicing of the sniffer sensor system.
- "**Chapter 7 Troubleshooting**" presents guidelines to provide solutions for combating failures.
- **" Annex A – ",** provides an extensive but exhaustive list of the different components of the sniffer sensor system.
- **"Annex B - Interface Connection** Documentation**",** provides details on the different connectors and wiring of the sniffer sensor system.
- **"Annex B - Block Diagram",** provides different diagrams that may help with the understanding of the sniffer sensor concept.
- "**Annex D - SCHEMES**" provides schemes of the parts of the sniffer system concept.

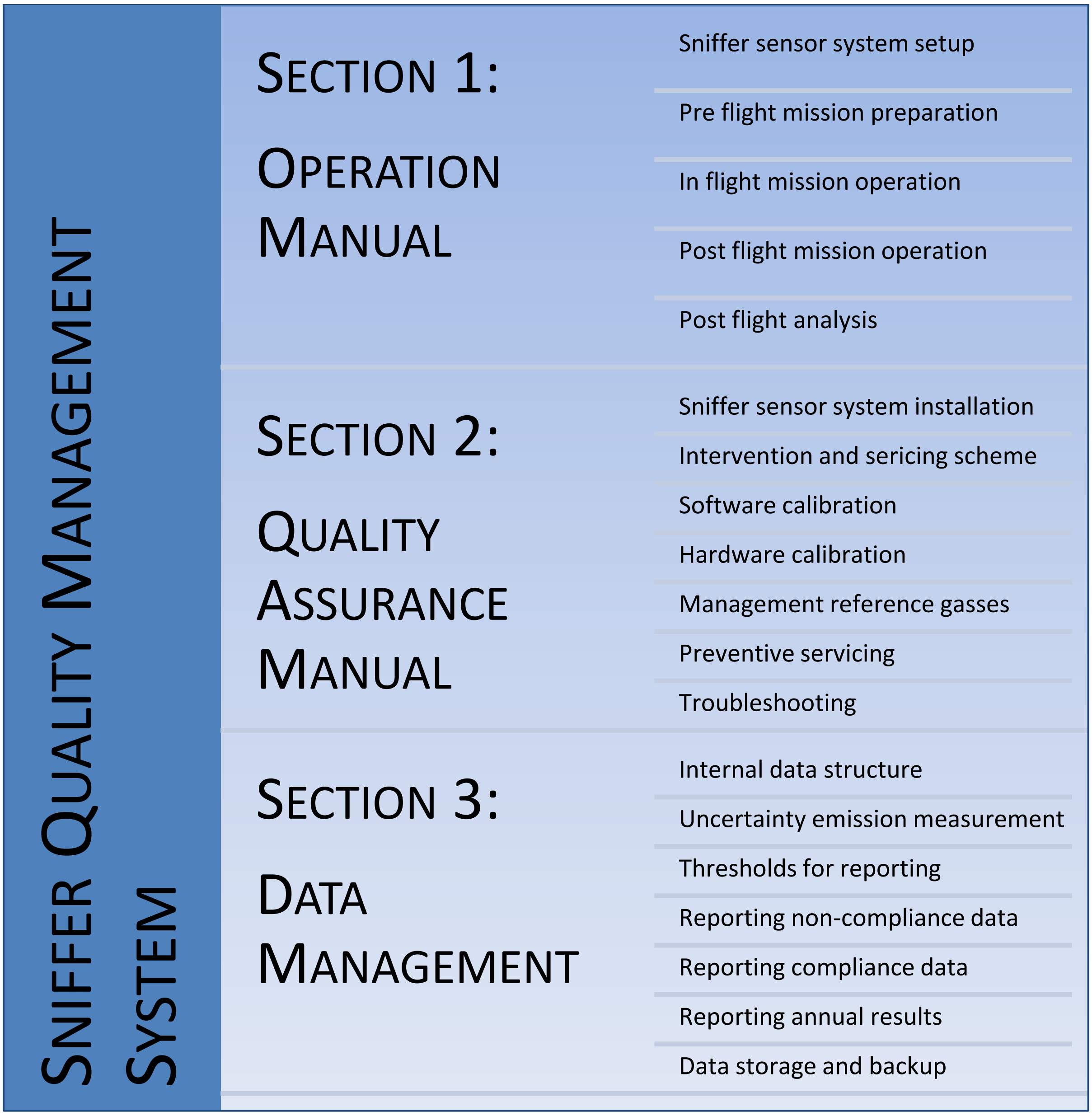


Figure 30 Sniffer QMS Structure

The sniffer sensor system manufactured by FluxSense (Sweden), consists of a compilation of components from different soft and hardware providers. This manual was composed by the scientific Service MUMM of the Royal Belgian Institute based on the different maintenance provisions of the components, applied on the specification of the sniffer sensor system on board of the Belgian Coastguard Aircraft and the nature of the Belgian North Sea Aerial Surveillance Program, as a result this manual may possibly not fully reflect the official opinion of the manufacturers.

INDEX

LIST OF SOPS

FIGURES

TABLES

CHAPTER 1. SNIFFER SENSOR SYSTEM INSTALLATION

The sniffer sensor system is the complete equipment setup used for airborne Marpol Annex VI monitoring. The sniffer sensor system is installed in a BN Islander type B2-A with immatriculation OO-MMM. The sniffer sensor installation is EASA certified by Airplus (Part 21 Design organisation). The certification is done with a minor change modification of the existing Surveillance system on board of the aircraft that was provided by Optimare and was EASA certified by Airplus in 2011. The EASA certification for the sniffer installation can be found in Annex E. The sniffer installation consists of following parts (a detailed part inventory list is available in " **Annex A – "):**

- Sniffer sensor
- Client stations
- Tubing
- Signal wiring
- Power distribution
- Sniffer equipment rack

1.1. Sniffer sensor

- The main component of the sniffer sensor installation is the sniffer sensor. The sniffer sensor was developed by Chalmers University and commercialized by FluxSense (Sweden). The sniffer sensor is a collection of different components and sensors that are installed in a custom-made casing (see also

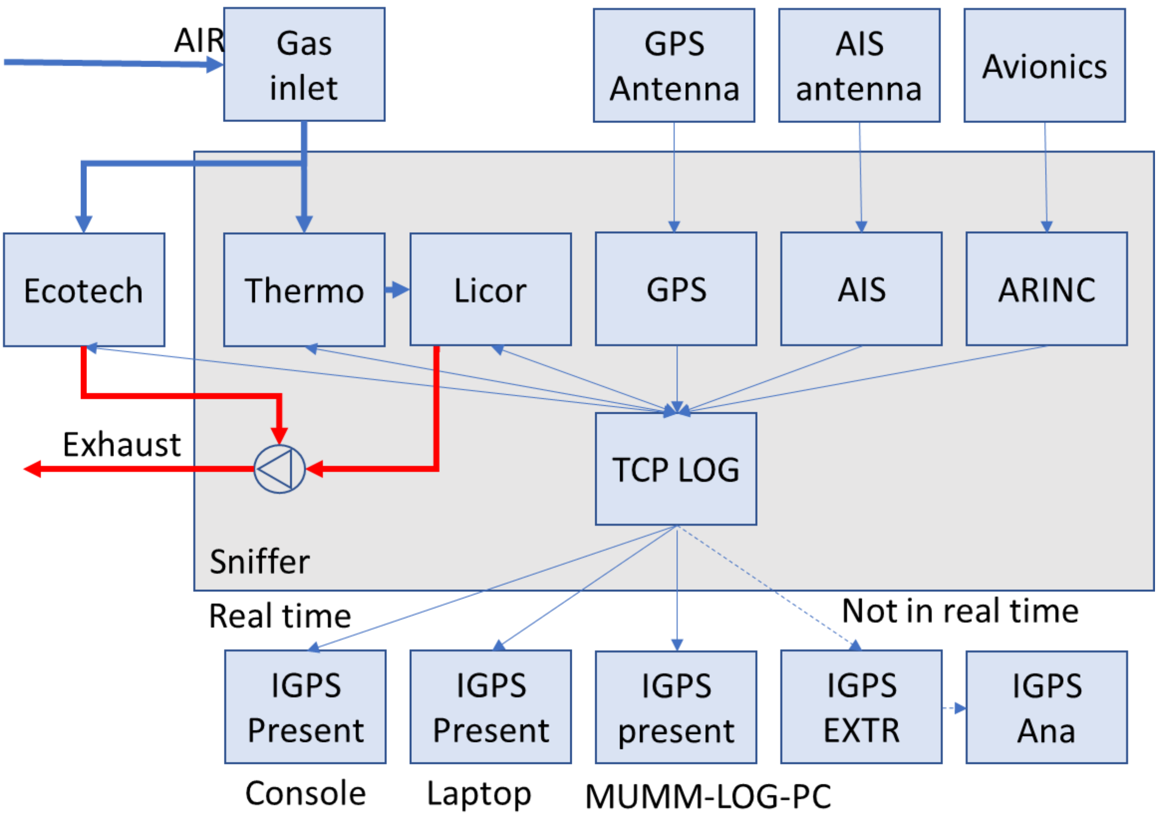


Figure 2 for schematic view of the sniffer sensor). The sensors consist of certified equipment used for ambient air quality monitoring that has been disassembled from its original case and reassembled in the sniffer sensor. The different components have been specially adapted for the purpose of airborne monitoring of ship exhausts. Therefore, some components were either reduced in size or removed, also the sample rate of the sensors has been increased to allow high speed continuous air quality measurements on board of fixed wing aircraft. The main components of the sniffer sensor are:

- Located in the upper part (seeFigure 34 Internal components of the sniffer system (lower part) (Note, the filters have been moved outside the sniffer to a filter box)):

  1. CO2 sensor
  2. SO2 sensor
  3. Hydrocarbon kicker
  4. Pressure and flow regulators
  5. Air pump (NOx)

- Located in the bottom part (see Figure 34):

  6. Log Computer
  7. AIS/GPS receiver
  8. ARINC reader
  9. Air pumps (2)

- Located in both compartments:

  10. Internal Tubing
  11. Internal power distribution
  12. Internal signal wiring
  13. Fans
  14. Casing

- Located outside the sniffer housing:

  15. NOx sensor
  16. Particle filter box
  17. BC sensor and Serial-Ethernet converter

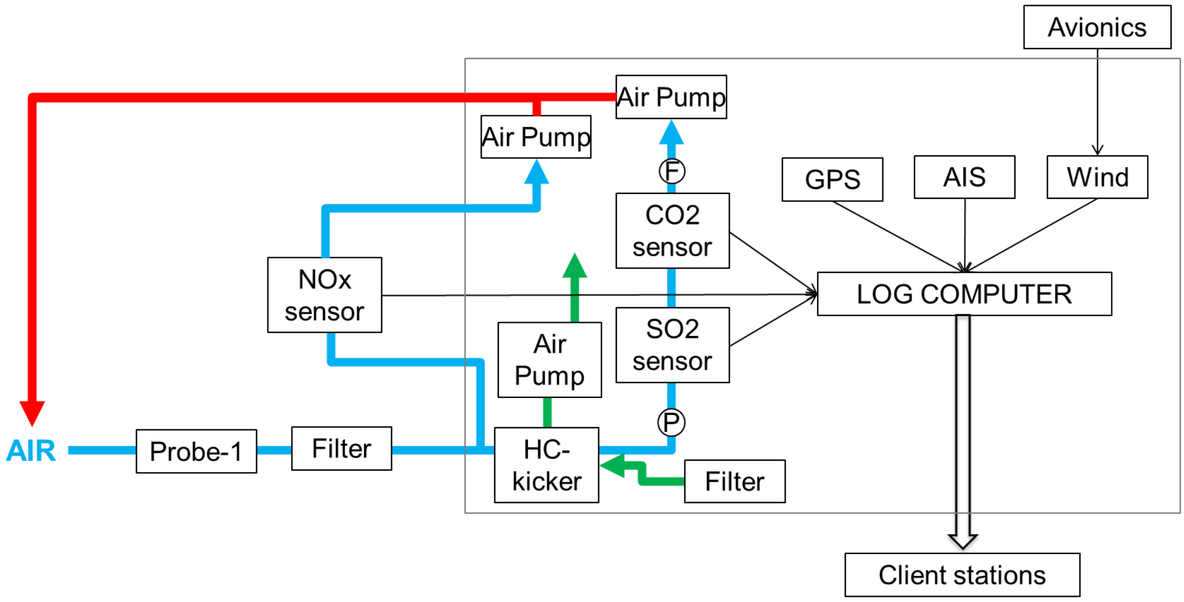


Figure 31 Block diagram of component of the Sniffer sensor

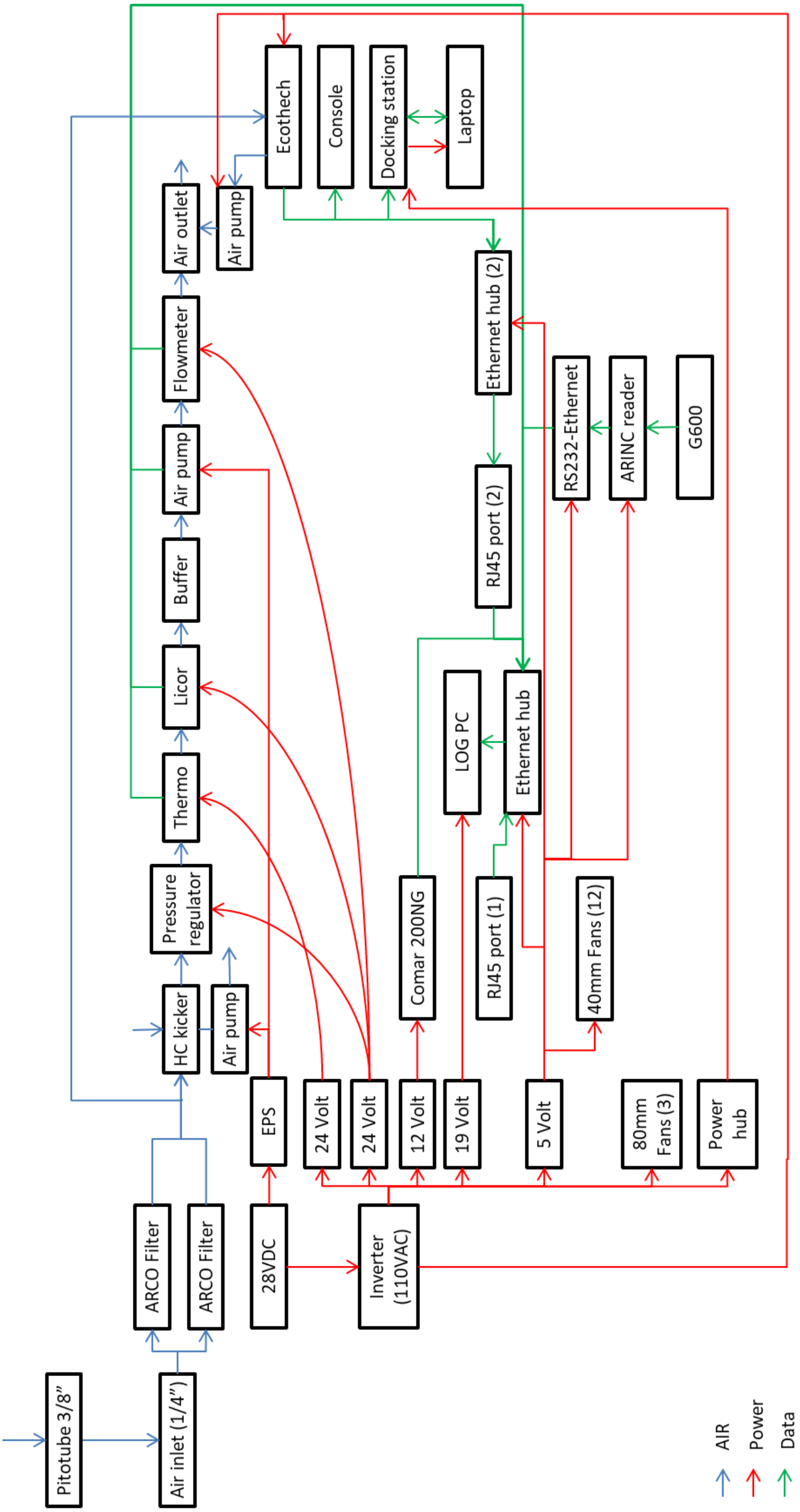


Figure 32 Schematic view of the internal component of the Sniffer sensor

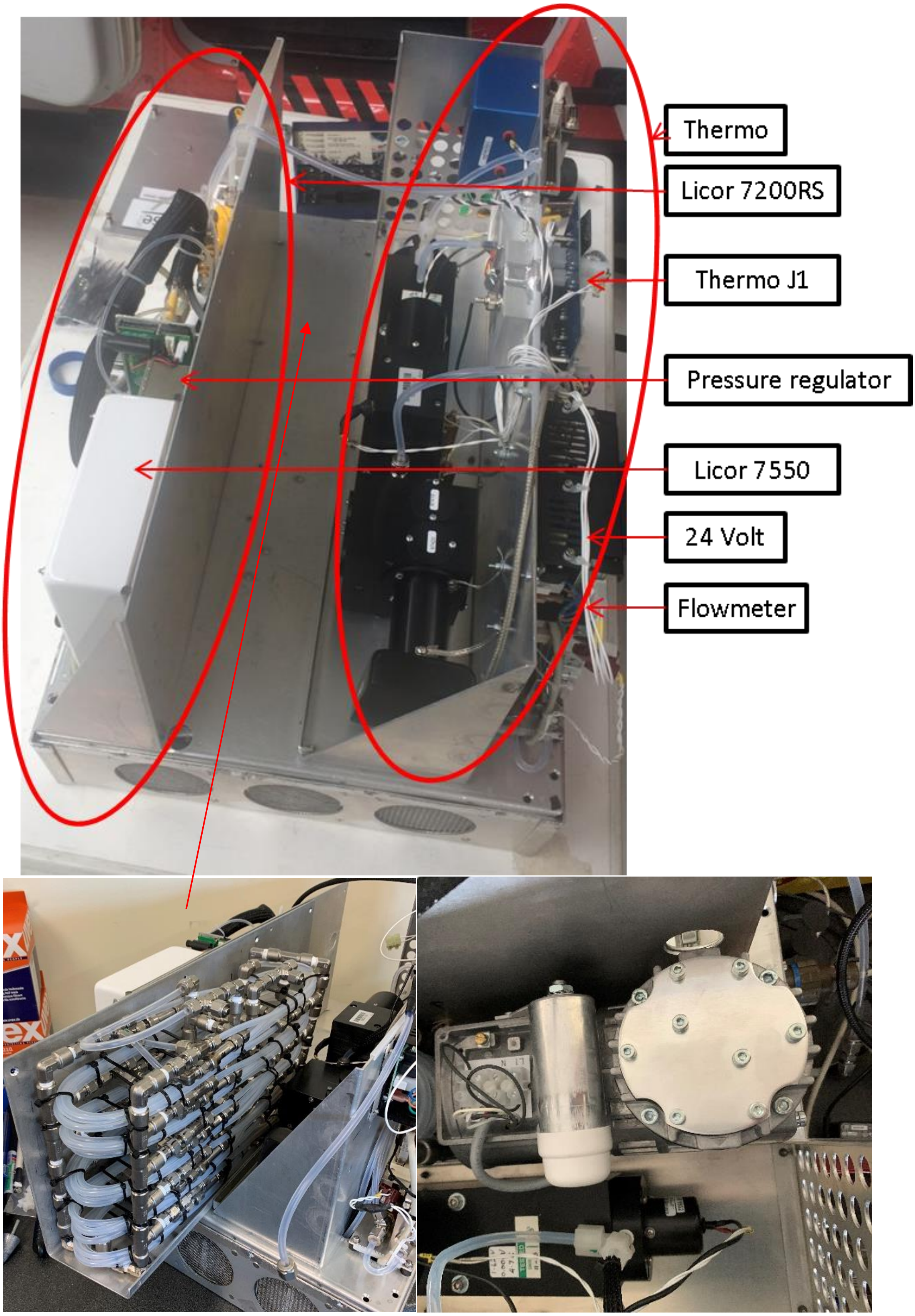


Figure 33 Figure 4 Internal Components of the sniffer system (upper part), (note the hydrocarbon kicker and NOx pump are installed on a removable tray in the empty part between the LICOR and the Thermo sensor).

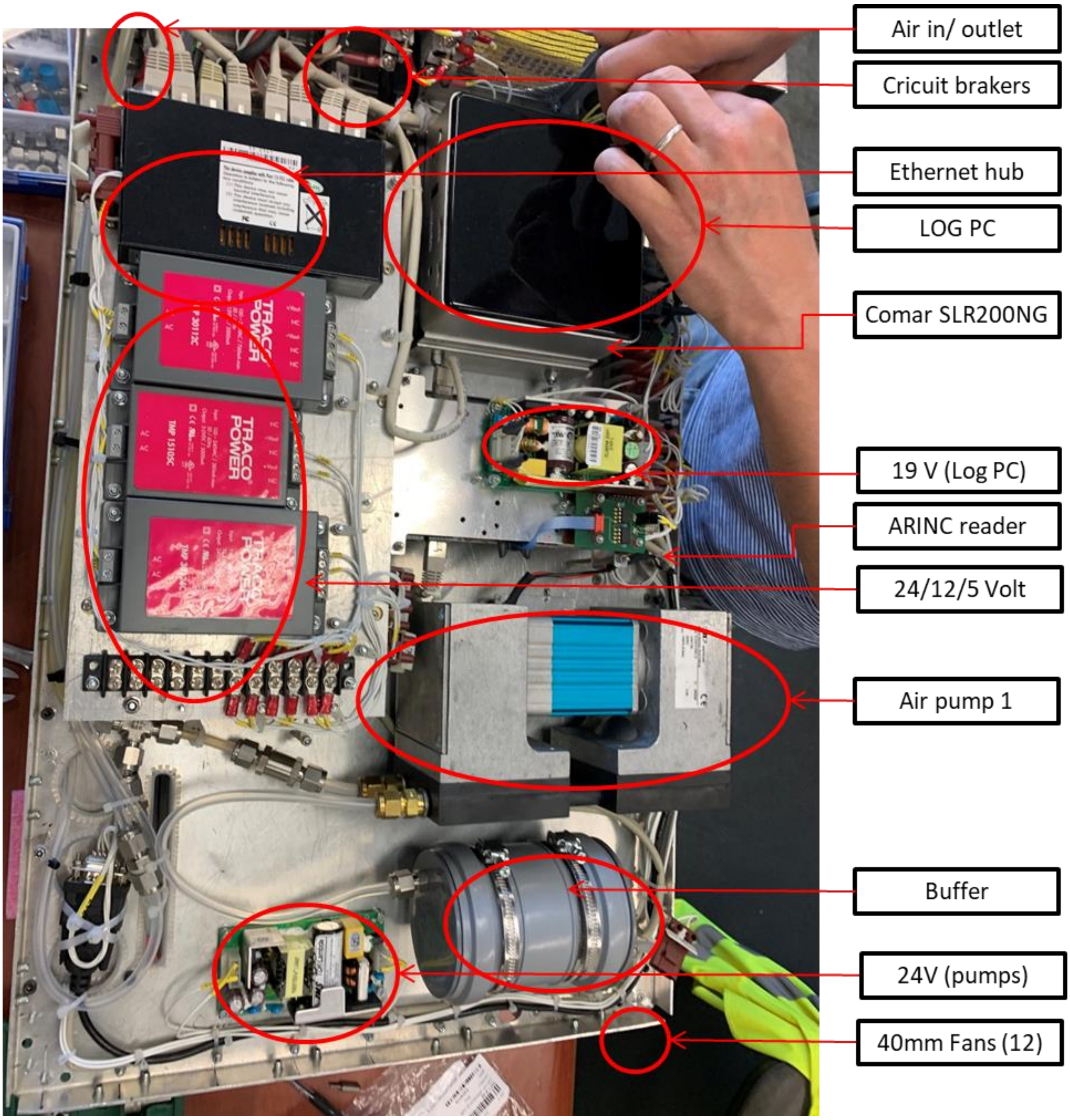


Figure 34 Internal components of the sniffer system (lower part) (Note, the filters have been moved outside the sniffer to a filter box)

1.1.1 CO2 sensor

The CO2 sensor that is used is the Biosciences Licor LI-7200RS combined with the Bioscience Licor LI-7550 analyser interface unit (see Figure 35). The LI-7200RS uses non-dispersive infrared spectroscopy to measure CO_2 and water vapour densities in air. It transmits infrared radiation through temperature-controlled optical filters, then through the closed sample path to a thermally regulated lead selenide detector. Some of the infrared radiation is absorbed by CO_2 and water vapour in the sample path. Gas densities are computed from the ratio of absorbed radiation to a reference. Only the CO2 concentration is used in the sniffer sensor system. The RS model is an improvement of the optical hardware resulting in a lower cleaning frequency of the optical components and lower drift. The LI-7200RS has following specifications:

- Ruggedized
- High speed measurement (5, 10 or 20 Hz)
- Calibration Range: 0 to 3000 µmol mol-1
- Accuracy: Within 1% of reading
- Zero Drift (per °C): ±0.1 ppm typical; ±0.3 ppm maximum
- RMS Noise (typical @ 370 ppm CO2): max 0.16 ppm (at 20 hz)
- Gain Drift (% of reading per °C @ 370 ppm): ±0.02% typical; ±0.1% maximum
- Direct Sensitivity to H2O (mol CO2 mol-1 H20): ±2.00E-05 typical; ±4.00E-05 maximum
- Data-output: RS232 and Ethernet

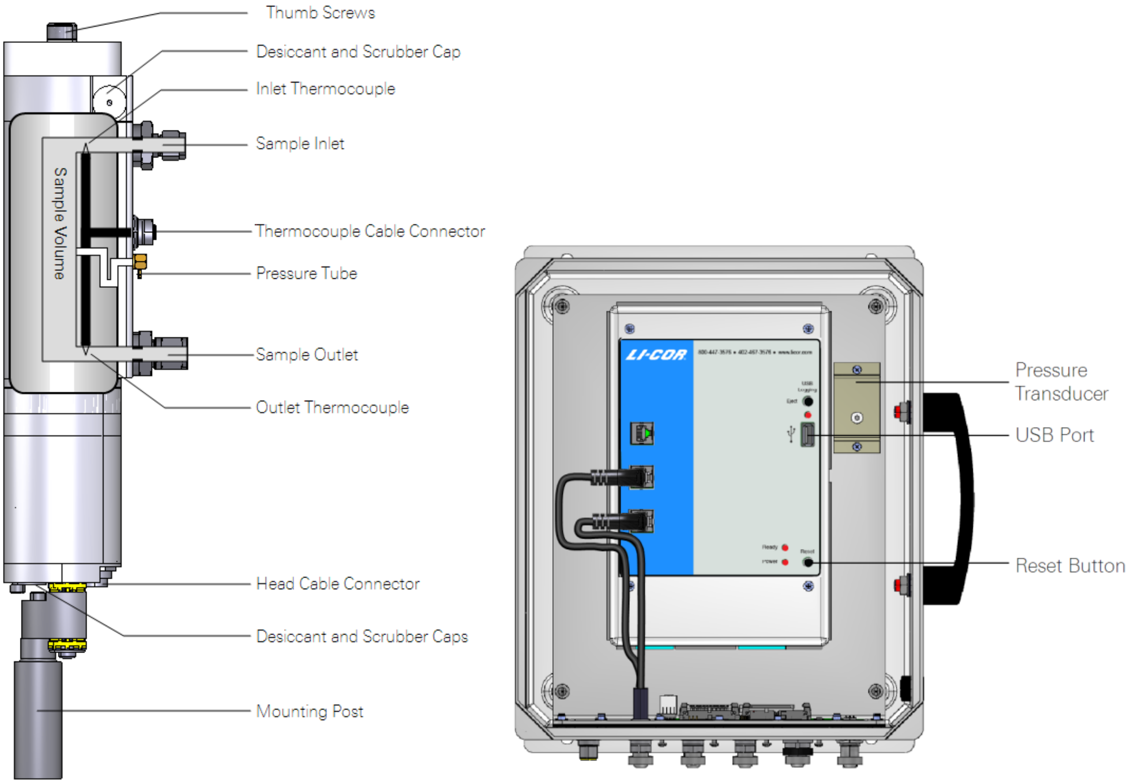


Figure 35 Schematic overview of the Licor7200RS (Biosciences 2015)

1.1.2 SO2 sensor

The SO2 sensor involves a Thermo Fischer Scientific 43i Trace Level Enhanced SO2 Analyser (see Figure 36). The sensor is based on the pulsed fluorescence technique for the measurement of SO2 concentration in ambient air, this technique operates on the principle that SO2 molecules absorb ultraviolet (UV) light and become excited at one wavelength, then decay to a lower energy state emitting UV light at a different wavelength.

The sensor is a Trace Level Enhanced (TLE) analyser, meaning it is a high sensitivity for analysing SO2. The sensing principle is linear and therefore only 1 span gas is required for its calibration. As the measurement of SO2 in exhaust gas is of the magnitude of 30 or more PPB no special zero calibration gas is necessary (CO2 reference gas in synthetic air is acceptable)

Specifications Thermo 43i TLE:

- High sensitivity (0.2 ppb)

- Fast response time
- Linearity through all ranges
- Totally self-contained
- Insensitive to changes in flow and ambient temperature
- User-selectable digital input/output capabilities
- Standard communications features include RS232/485 and Ethernet
- Limited drift (zero drift: <0.2 ppb / 24h – Span drift: 1% per week)

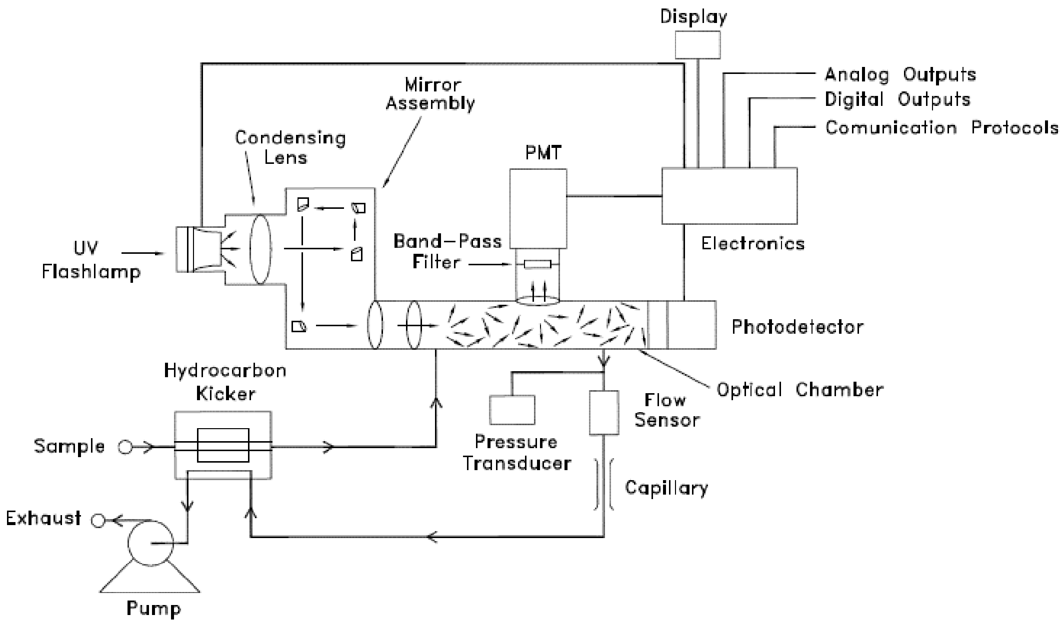


Figure 36 Schematic flow of the Thermo 43i TLE, the hydrocarbon kicker is not used in the sniffer sensor setup

1.1.3 NOx sensor

De NOx sensor used in the sniffer sensor system is a Ecotech Serinus 40 NOx analyser. The instrument uses gas-phase chemiluminescence detection to perform continuous analysis of nitric oxide (NO), total oxides of nitrogen (NOX), and nitrogen dioxide (NO2). This is achieved by using one primary reaction cell and drawing the sample through two separate paths controlled by the main controller PCA. The instrument consists of a pneumatic system, an NO2 to NO converter, a reaction cell, a measurement cell (PMT), an ozone generator and a main controller PCA.

The analysis of nitrogen oxides by chemiluminescence is based on the luminescence from an activated molecular NO2 species produced by the reaction between NO and O3 in an evacuated chamber. The NO molecules react with ozone to form the activated species NO2* according to the reaction mechanism:

$NO + O_3 \rightarrow NO_2^* + O_2$

Equation 1 – Chemiluminescence Reaction for NO

As the activated species NO2* reverts to a lower energy state, it emits broad-band radiation from 500 to 3000 nm, with a maximum intensity at approximately 1100 nm. Since one NO molecule is required to form one NO2* molecule, the intensity of the Chemiluminescent reaction is directly proportional to the NO concentration within the sample. The PMT current is then directly proportional to the chemiluminescence intensity.

Any NO present in the sample, when drawn through the NO path, reacts with ozone in the reaction cell resulting in the NO measurement. Any NO or NO_2 present in the sample when drawn through the NO_x path, first passes through the NO to NO_2 converter. This process allows the NO to pass through unaffected but converts any NO_2 in the sample into NO. Thus the total NO (NO + converted NO_2) in the NO_x path reacts with ozone in the reaction cell resulting in the NO_x measurement.
In the reaction cell energy is released in the form of chemiluminescent radiation, which is filtered by an optical bandpass filter and detected by the photomultiplier tube (PMT). The level of chemiluminescence detected is directly proportionally to the concentration of NO in the sample.
The concentration of NO_2 is calculated by subtracting the NO measurement from NO_x measurement.

$NO_x = NO + NO_2$ Or $NO_2 = NO_x – NO$

The system can be remotely access by using the serinus application on android devices, this application copies the display and control buttons of the NOx sensor display

Figure 37 Ecothech Serinus 40 NOx analyser (lef) and remote Serinus application for Android devices

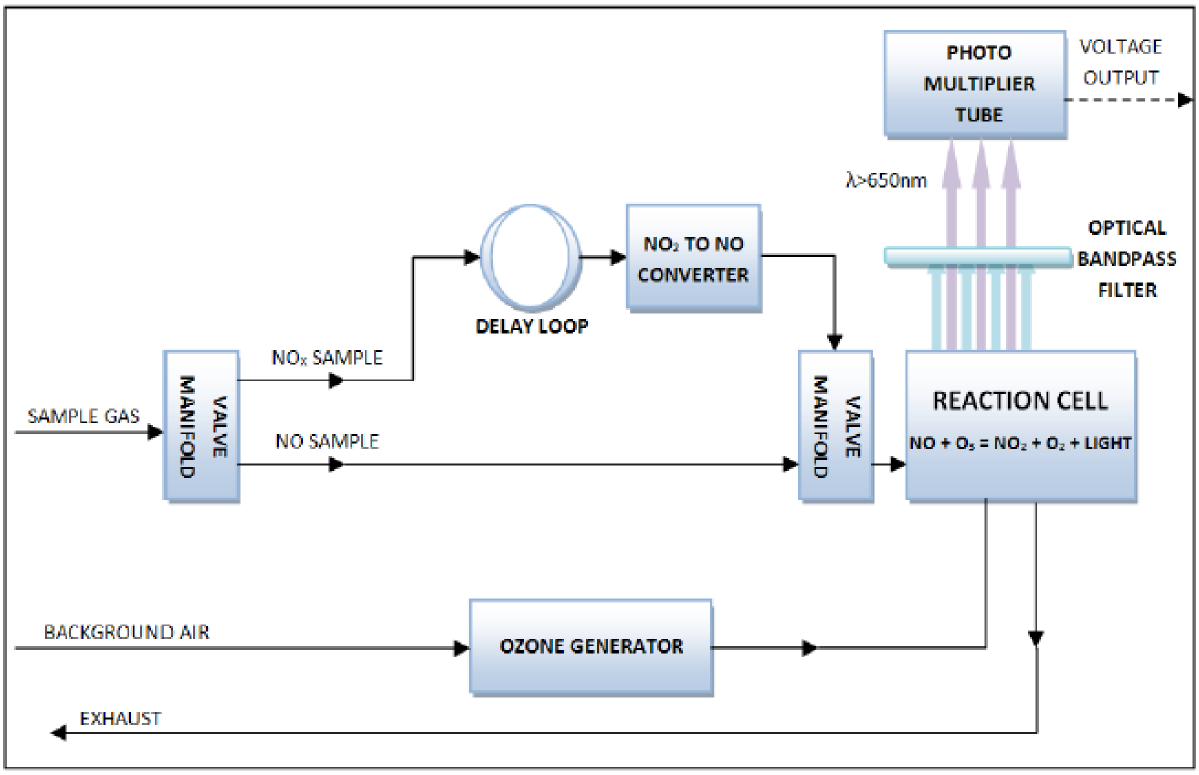


Figure 38 Schematic flow of the Ecotech Serinus 40 NOx sensor, the Delay loop is not used in the sniffer sensor system as this would provide different result time for NO and NOx measurement

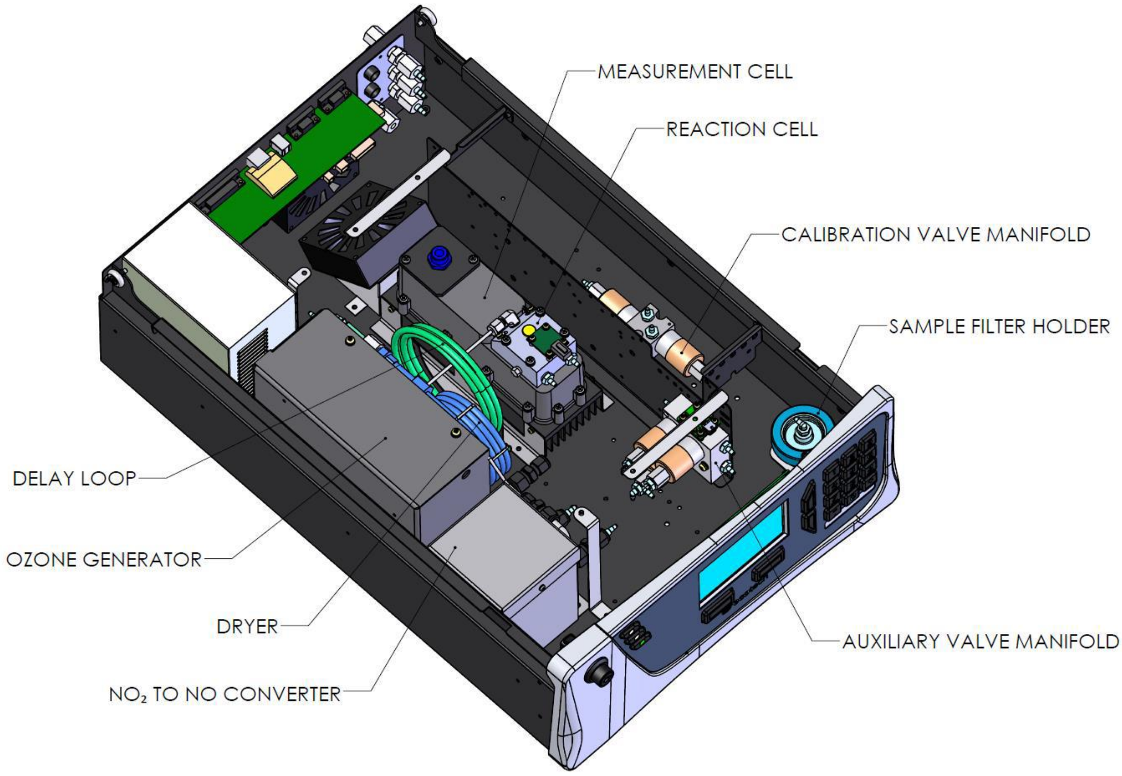


Figure 39 Schematic overview of Ecothech Serinus 40 NOx sensor system (note that the delay loop and sample filter are not used)

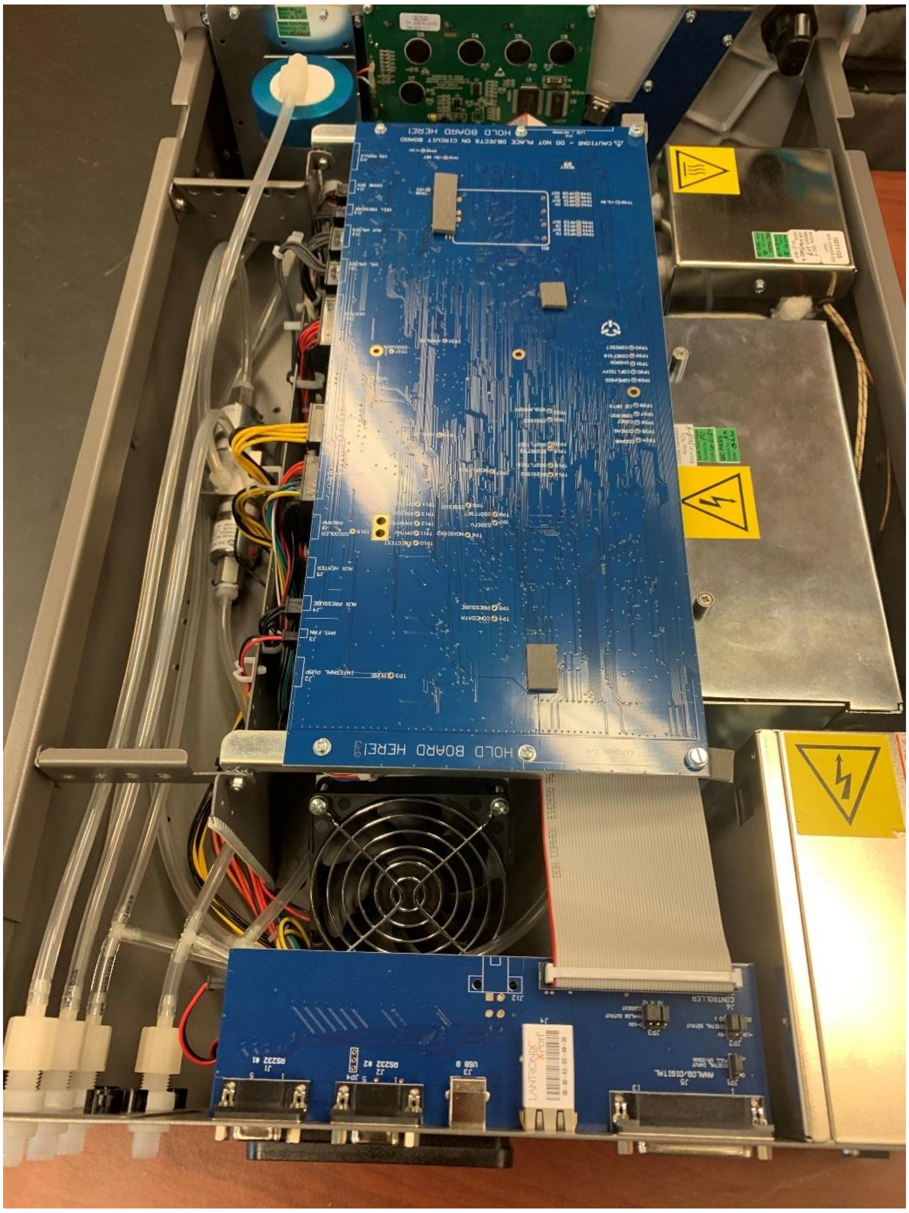


Figure 40 internal parts of the NOx sensor

Note: The "Delay loop" is bypassed from the NOx sensor to reduce the time between measurement and display in NOx mode. If for some reason the sensor needs to be operating back in the "All" mode (to measure the NO2), this delay loop must be re-installed.

1.1.4 Pressure and flow regulators

A flow controller (EL-FLOW F-201CV Mass Flow Controller (MFC)) and pressure meter (EL-PRESS P-502C Pressure Meter with F-004AC valve for low ΔP applications) from Bronkhorst are installed inside the sniffer sensor to ensure a constant and stable airflow through the sniffer sensor system (see Figure 41).

The control valve of the EL-FLOW F-201CV Mass Flow Controller (MFC) forms a closed loop pressure control system with the EL-PRESS P-502C Pressure Transducer, the Mass Flow Meter of the MFC measures the required flow rate to maintain a pressure level 70-80% of the atmospheric pressure. The setpoint voltage divider enables to adjust the maximum flow to build up the required pressure level.

The Bronkhorst regulators are connected to the Ethernet network with both a Flowbus and a RS232 to Ethernet connection.

Specifications (combined):

- Accuracy: ±0.5% FS
- Repeatability: <0.1% RD
- Pressure range: 1:50
- Response time: 2msec
- Control stability: < ±0.05%FS
- Operating temp: -10-70°C
- Temperature sensitivity: 0.1% FS/°C
- Attitude sensitivity: <0.3 mbar
- Max Kv value 6.6x10^{-2} (F-201CV)
- Warmup time: 30 secs (F-201CV)
- Power: 15-24Vdc <300mA
- Communication: RS232

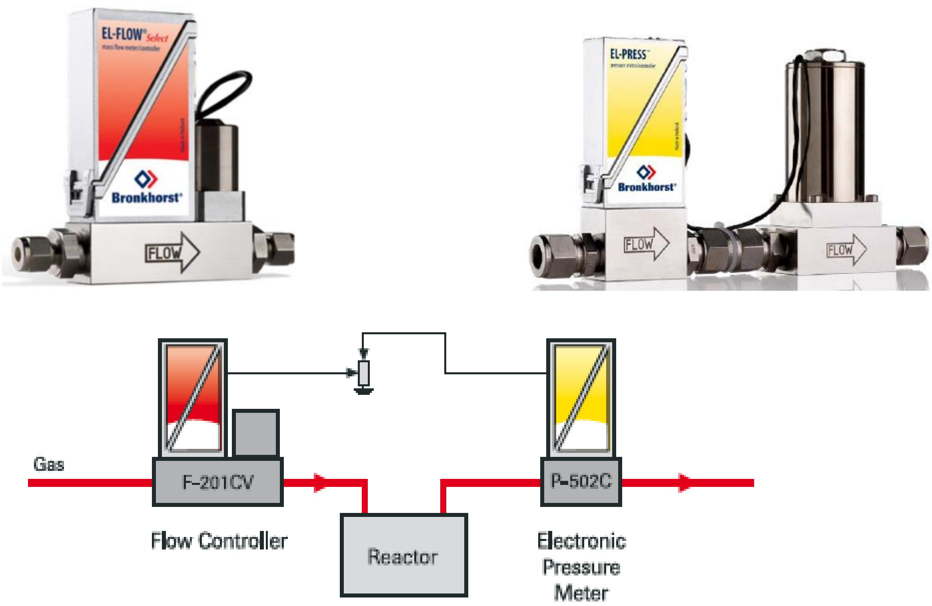


Figure 41 Setup of the flow controller and pressure meter

1.1.5 MUMM_LOG_PC

A Zotac Zbox Nano ID64 mini pc is installed in the sniffer (see Figure 42), this mini pc is further referred as the MUMM_LOG_PC. The MUMM_LOG_PC centralizes the data acquisition and data output to the different client users via Ethernet. One USB port is connected to the external USB connector, this can be used to connect external devices (keyboard, mouse, drives, …) or for troubleshooting. The HDMI output of this PC is connected to an external HDMI connector and used for the visualisation of the IGPS navigation charts to the cockpitdisplay (VGA2 on Avalex AVM 4095) via an HDMI to VGA converter which is installed outside the sniffer sensor. The BIOS has been modified to startup after connecting to power supply. Wake-On LAN has been activated (based on Mac Address).

The basic characteristics of the MUMM_LOG_PC are

- Manufacturer: Zotac
- Model: Zbox Nano ID64
- Operating system: Microsoft Windows 7 professional (64 bit) version 6.1.7601 SP 1
- Processor: Intel(R) Core(TM) i5-3337U CPU @ 1.80GHz, 1801 Mhz, 2 Core(s), 4 Logical Processor(s)
- Memory: 8GB RAM
- Hard Drive: Samsung EVO 850 2.5" of 1 TB (original: WD 10JFCX HDD of 1TB)
- Mac Address: 00012E4D9E04

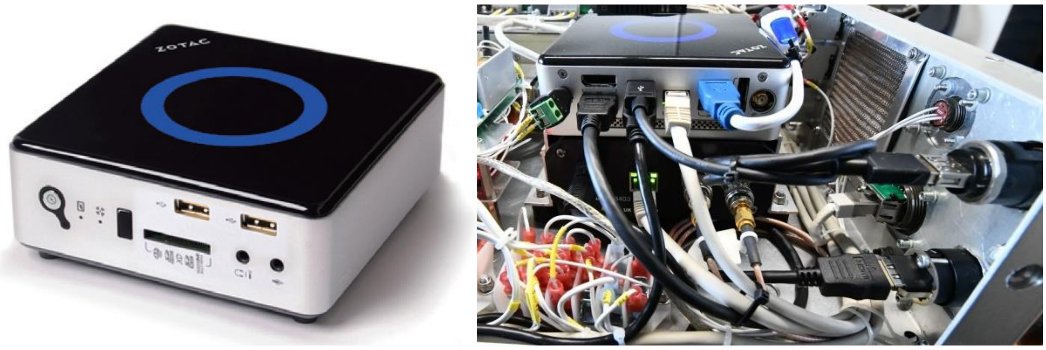


Figure 42 Zotac Zbox Nano ID64 unit with different connections

To access the internal MUMM_LOG_PC, a remote connection can be realized using TeamViewer (V12) or Windows remote desktop. The IP address of the MUMM_LOG_PC is 192.168.1.9 with login name “MUMM” and password “mumm”. To enable this connection the IP configuration of the client stations have to be adjusted (see 1.7 External signal wiring)

1.1.6 AIS+GPS receiver

The network NMEA AIS+GPS receiver used in the sniffer sensor consist of a Comar SLR200NG receiver (see Figure 43). A VHF antenna is installed on the belly of the aircraft and connected to the ASP connector panel (TNC), a GPS receiver is installed on the top of the aircraft and connected to the ASP connector panel (TNC). The receiver is located in the bottom compartment of the sniffer under the LOG PC (see Figure 42) and is attached to the frame with M7 and M8 locknuts.

Specifications AIS+GPS

- Manufacturer: Comar
- Type: SLAR200NG
- Connectors: VHF Antenna BNC; GPS Antenna TNC
- Output Port: RJ45 Ethernet port
- Power Supply Range: 9 – 30 Volts dc
- Power Consumption: 400 mW
- Output Baud Rate: 38,400 Baud

Specifications GPS antenna

- Manufacturer: Cobham
- Type: CI 401-220
- LNA
- Frequency: 1575.42 +/-3 MHz
- VSWR: 1.5:1 Maximum
- Polarization: RHCP

- Radiation Pattern Hemispherical
- Output Impedance: 50 Ohms
- Gain @ 1575.42 MHz 26.5-31.5 dB
- DC Voltage 4 to 24 Volts
- DC Current Min/Max 25mA / 40 mA
- Noise Figure 3.8 dB
- Selectivity: -40 dB Min. @ Satcom 1626.5 MHz

Specifications VHF antenna

- Manufacturer: Cobham
- Type: CI 292-3
- Frequency : 136-174 & 138-174 MH
- Gain: 2.5 dB Minimum
- Impedance: 50 Ω
- Polarization: Vertical
- Patter: Omnidirectional
- Power: 50 Watts

Figure 43 Comar SLR200NG receiver, Cobham VHF antenna and Cobham GPS antenna

1.1.7 Arinc

An Arinc converter is installed in the sniffer (Olimex ARINC ADC 20160815) and connected with a 5 volt RS232-Ethernet converter. This device translates the navigation information coming from the aircraft avionics (Garmin G6TN650) ASP-CON-06 (Pin1-3), the Arinc data stream contains a great number of navigation data, but currently only the wind information is used by the sniffer sensor system (labels 315 and 316).

2018-08-2210:51:39.720100,from,192.168.1.121:9760,ADC,-1,-1,348,482,609,-1,715,682,686,688,691,686,-1,-1,-1,-1

Table 5 ASP-CON-06 specifications

	Description	Manufacturer
Connector Type Chasis	D38999/20FE35PN-LC	Amphenol
Contact Type Chasis	55x Male	Amphenol
Shell Size Chasis	17	Amphenol
Connector Type Cable end	D3899/26FE35PN-LC	Amphenol
Contact Type Cable end	55x Female	Amphenol
Shell Size Cable end	17	Amphenol

PIN	Conductor Type	Signal Name	Signal Logic / Load (A)
1	AWG 22 Double shielded	Arinc 429 TX A (from GTN 650 nr 1)	
2	AWG 22 Double shielded	Arinc 429 TX B (from GTN 650 nr 1)	
3	AWG 22 Return	Arinc 429 Return (from GTN 650 nr 1)	

Table 6 Available data labels on the Arinc signal from the Garmin GTN650 (100 Hz)

Label	Parameter	Range	Sig bits	Resolution	Update interval
150	Greenwich Mean Time	0-23 h 0-59 m 0-59 s		1 s	1 Hz
204	Baro altitude	±131072 ft		1 ft	1 Hz
260	Date			1 day	1 Hz
310	Latitude	±180°		0.00017°	10 Hz
311	Longitude	±180°		0.00017°	10 Hz
312	Ground Speed	4096 kn		0.1 kn	1 Hz
313	True Track	±180°		0.1°	1 Hz
314	True Heading	±180°		0.1°	10 Hz
315	Wind Speed	255 kn		1 kn	1 Hz
316	True Wind Direction	±180°		1°	1 Hz
(317)	(Magnetic Track)	(±180°)		(0.1 °)	(1 Hz)
321	Drift Angle	±180°		0.1°	10 Hz
324	Pitch Angle	±180°		0.1°	10 Hz
325	Roll Angle	±180°		0.1°	10 Hz

1.1.8 Air pumps

There are in total 3 pumps used in the sniffer sensor system, the first pump is used for the CO_2 and SO_2 sensors, the second pump is used for the hydrocarbon Kicker and the third pump is used for the NO_x sensor. The pump used for the SO_2 and CO_2 sensor, is the main pump in the sniffer sensor (838.1.2 KNDC-B), this is a two headed pump (replaced the former one headed main pump in 2021):

- Manufacturer: KNF
- TYPE: PJ33413-838.1.2
- NO: 15207799
- U: 24 VDC (3.7 A)
- Pmax: +50kPa (0.5bar)
- Flow at barometric pressure: 60l /min
- Weight: 3 kg

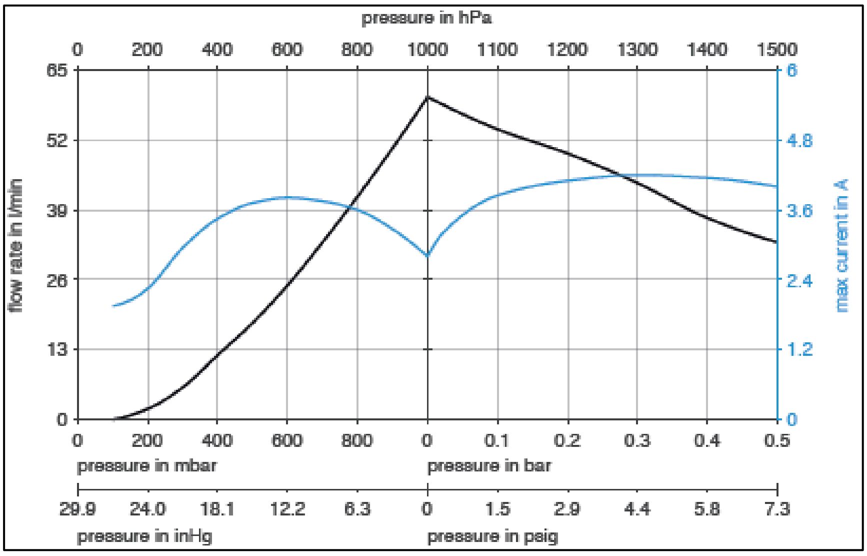


Figure 44 Pressure diagram KNF N_838.1.2 KNDC-B

A buffer (PVC tube of 10 cm diameter and ca. 15 cm long) is installed just before the pump-inlet. The pressure in the sniffer system is ca 600 mm Hg (800mbar), the actual airflow is ca 15 l/min. This circuit is pressure and flow controlled by the Bronkhorst regulators (see further). The pump used for the hydrocarbon kicker is the former main pump (838.1 KNDC-B), this pump provides an under pressure for the removal of the VOC particles in the hydrocarbon kicker.

- Manufacturer: KNF
- TYPE: PM26726-838
- NO: 9315084
- U: 24 VDC (3.7 A)
- Pmax: +50kPa (0.5bar)
- Flow at barometric pressure: 32l /min
- Weight: 2.2 kg

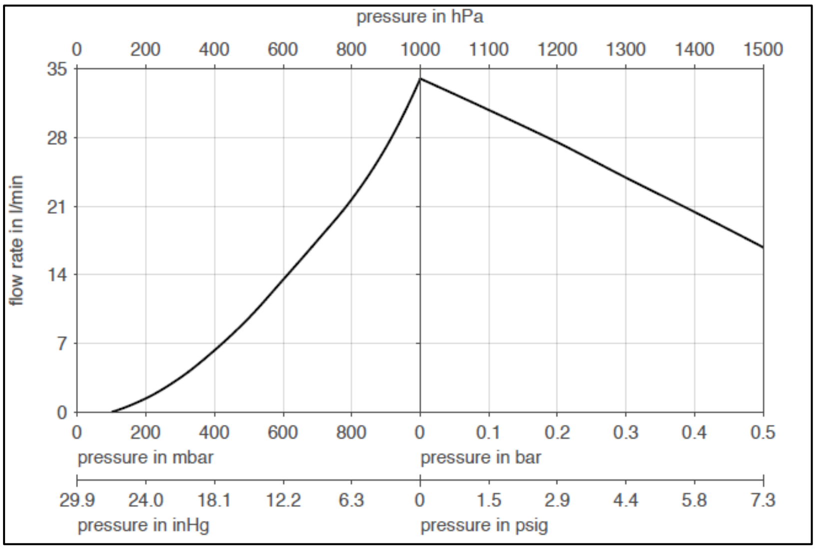


Figure 45 Pressure diagram KNF N_838.1 KNDC-B

The third pump (N 026 ATE) is used in the NO_x circuit, the airflow is split between the particle filter and the pressure regulator, this circuit goes to the NOx sensor and comes back to the sniffer sensor where it is connected to the following pump

- Manufacturer: KNF
- TYPE: N 022 ATE
- NO: PM32615-N022
- U: 110 VAC (2 A)
- Pmax: 2.5bar
- Ultimate vacuum pressure: 100mbar
- Flow at barometric pressure: 17l /min
- Weight: 5 kg

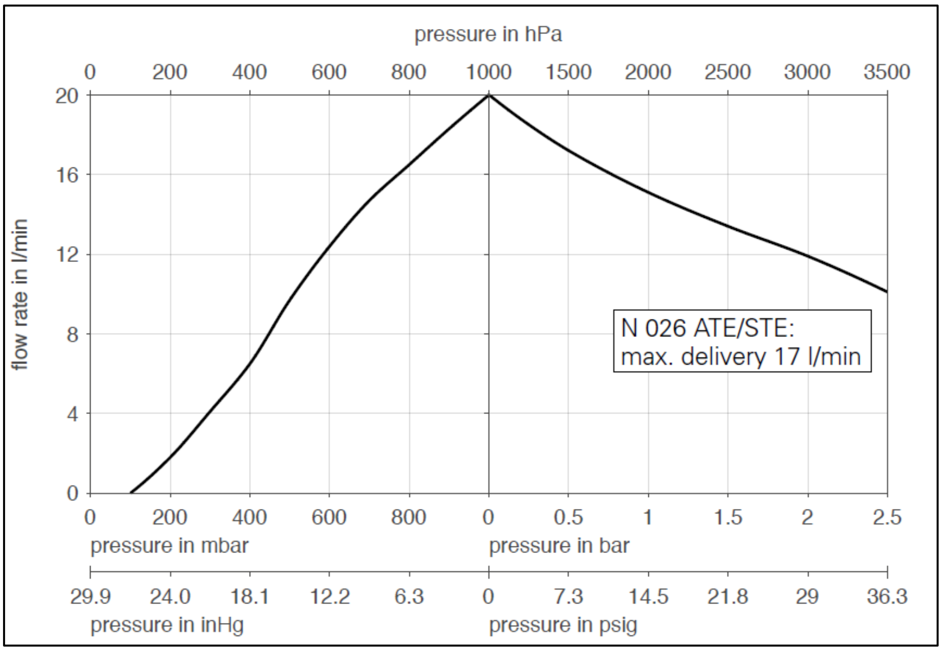


Figure 46 Pressure diagram N 026 ATE

1.1.9 Internal tubing

1.1.10 Almost all tubing inside the sniffer sensor is done with 1/4" Swagelok stainless steel fittings and 1/4" Teflon tubing (see 1.2.3 Connecting to the sniffer

The Sniffer sensor setup is based on a network environment, all data is logged on the sniffer sensor internal computer MUMM_LOG_PC, this data can be accessed from different client stations following client stations are used during operations:

- MUMM_LOG_PC: for visualisation of the MAP to the cockpitdisplay (on MAP2)
- Operator Laptop: for manual calculation of the FSC
- Console: for strategic overview, guiding pilots and plotting graphs on VIDEO 2 on cockpitdisplay

To connect different client stations to the sniffer sensor a set of predefined IP addresses need to be used (Table 1), for more information on how to set the IP address see Section 3 of the SQMS.

Table 1 IP addresses for external connection to the sniffer sensor

IP addresses	User

192.168.1.230 -239	available
192.168.1.240	Console via VM
192.168.1.241	PC Ward via Thunderbolt dock
192.168.1.242	PC Kobe via Thunderbolt dock
192.168.1.243	PC Annelore via Thunderbolt dock
192.168.1.244	PC Benjamin via Thunderbolt dock
192.168.1.245	PC Ward via cable
192.168.1.246	PC Kobe via cable
192.168.1.247	PC Annelore via cable
192.168.1.249	PC Benjamin via cable

1.2. NOx sensor

A NOx sensor was added to the sniffer sensor system. The sensor is an Ecothech Serinus 40. The sensor is installed in the back of the aircraft. A protection plate is installed in the front of the sensor protecting it from accidental touches on the control buttons. All commands go through a smartphone with the Serinus application connected through Bluetooth.

Figure 7 NOx sensor installed in the rear luggage compartment (here displayed without the protective front panel)

1.3. Client station

In theory a vast amount of client stations can be connected to the Sniffer by using ethernet. For operational use, only 2 client stations are connected to the sniffer. The first being the console and the second being the operator laptop via Thunderbolt dock. This means that together with the MUMM_LOG_PC constantly 3 computers are receiving the sensor data and can be used for navigation and analysing the measurements.

1.3.1 Console (MMU)

The MMU is the main console in the aircraft used for the Medusa system. The MMU runs on a tailored Open Suse Linux Platform and is therefore not suited for the installation of the IGPS software. A Virtual Machine (VM Player) with a Windows XP installation is installed on the MMU to allow to run IGPS on the console.

To enable direct Ethernet connection from the VM to the Sniffer sensor an additional Ethernet cable was installed (from J221 to an Ethernet hub inside the console). The IGPS software is installed on the "C:" drive of this VM XP distribution. The firewall has been deactivated for the IGPS software.

An additional USB to VGA adapter is installed on the VM. This allows the presentation of the VM display (SNF view of the AISPresent.exe) to the cockpit display and G600 (Video 2).

1.3.2 Laptop with RAM mount and WiGig dock

The operator laptops (Dell Lattitude 5420) have been specially selected and purchased for the conduction of sniffer flights. A special RAM laptop mount has been installed on the right side of the cabin to allow the laptop operator to work freely. To avoid issues with multiple cables a Startech thunderbolt docking station has been installed on the front side of the console, the laptop is connected to a 2 m thunderbolt cable providing, data (ethernet, USB, HDMI) and power. The thunderbolt dock and laptops are powered by 115V power connector on the Sniffer (J233).

Figure 8 RAM mount for installation operator laptop

for more information), except from the exhaust tubing (from the confluence of 2 outgoing pumps 1 and 3), this section is done in 3/8 tubing to allow for an optimal release. As the NOx sensor emits ozone, an exhaust was added and one-way check valves are installed at the outlet of the pumps.

1.3.3 Hydrocarbon kicker

A special hydrocarbon kicker has been developed to remove hydrocarbons from the airflow to the SO2 sensor. This hydrocarbon kicker consists of 10 parallel installed standard Thermo 43i hydrocarbon kickers from decommissioned Thermo 43i sensors (Figure 47).

The working mechanism is based on semipermeable tubing in an inner compartment. Air flows inside this tubing towards the SO2 sensor. A dedicated pump creates an airflow in the outer compartment. Due to capillaries that are the start of this outer compartment an under pressure is created. This under pressure draws hydrocarbons through the semipermeable wall (Figure 48)

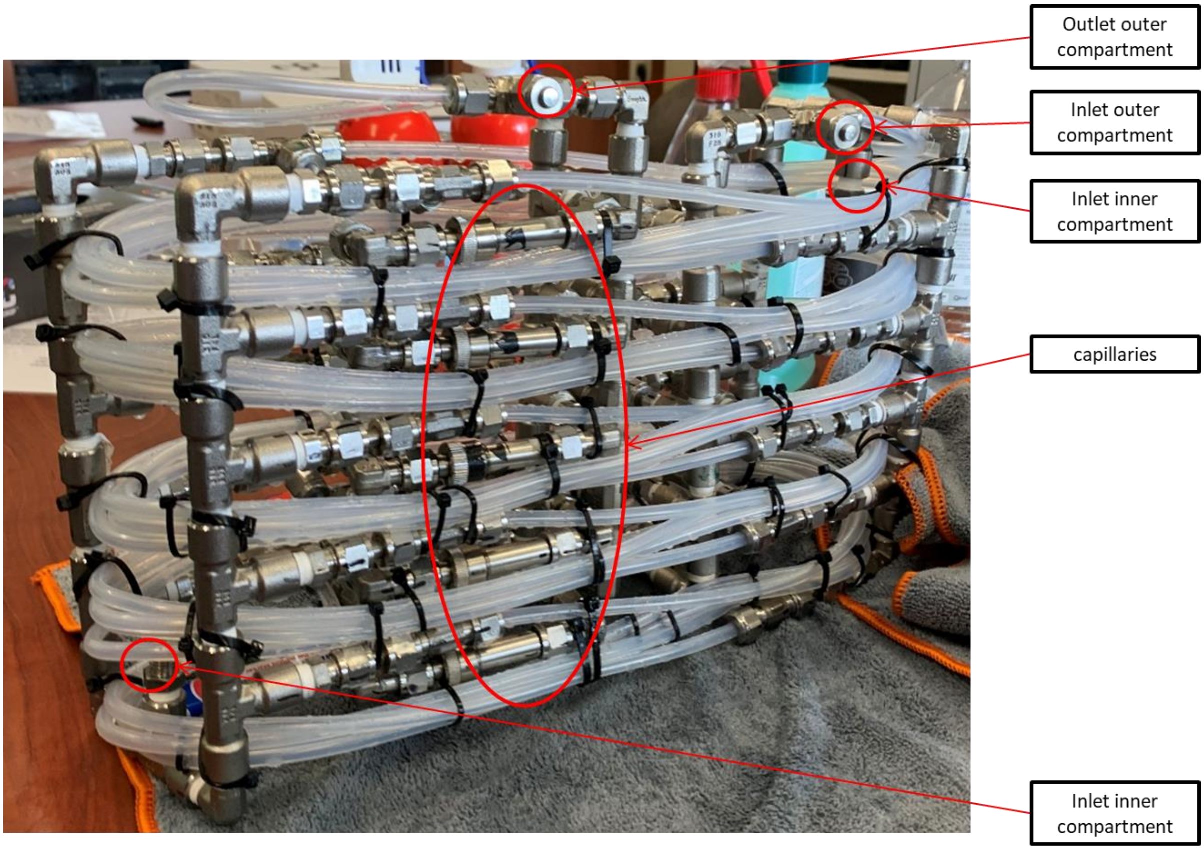


Figure 47 Custom designed hydrocarbon kicker

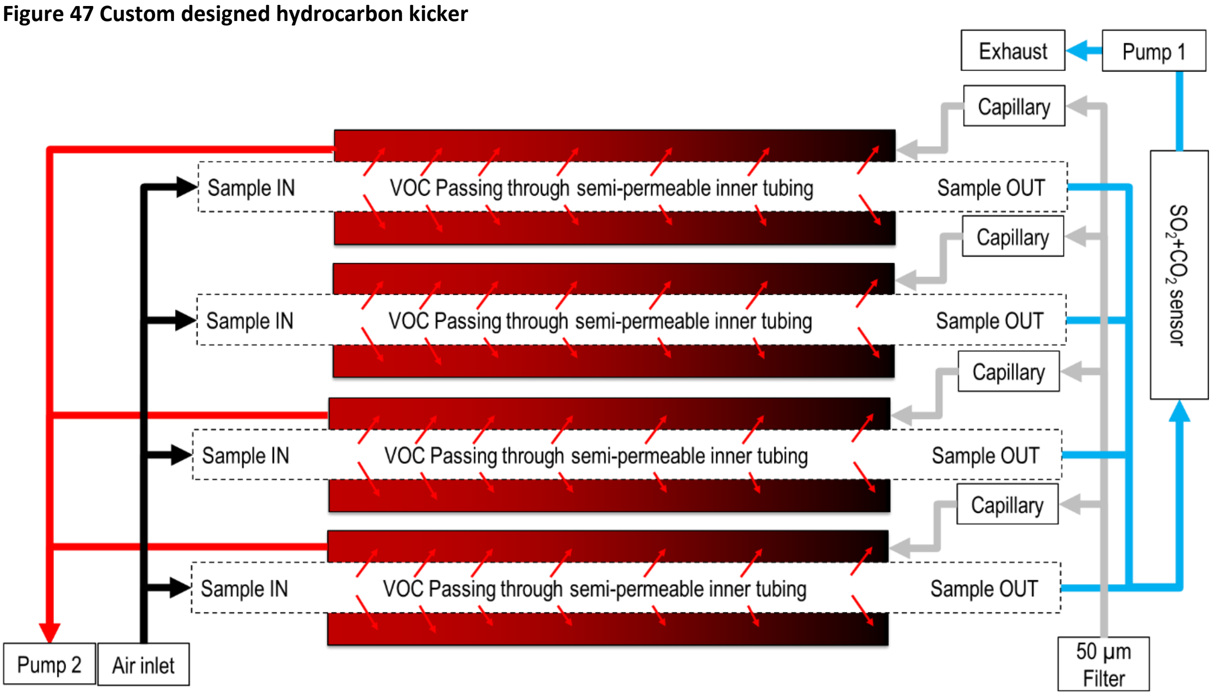


Figure 48 Schematic drawing of the hydrocarbon kicker

1.3.4 Internal signal wiring

A standard 5VDC 8 port RJ45 Ethernet hub (MXU85A0001) is used to connect all the different Ethernet connectors from the components to the MUMM_LOG_PC and client station. The internal main IP addresses in the sniffer sensor are displayed in Table 7.

Table 7 IP addresses used in the sniffer sensor

IP address	Component	Port
192.168.1.19	Co.Pilot Present	
192.168.1.9	Logger internal computer	
192.168.1. 95	Licor7200	7200
192.168.1.201	Thermo TLE 43i	Command: 9880 Stream: 9881
192.168.1.110	Comar AIS+GPS	10001
192.168.1.102	Bronkhorst Flowbus	1471
192.168.1.130 (CPC-3787) 192.168.1.106 (CPC-3787-RS232)	Bronkhorst pressure control: Ethernet to RS232	23 1470
192.168.1.121	ARINC receiver	9760
192.168.1.213	Ecotech Serinus 4.0	Serial port 97

1.3.5 Internal power distribution

The sniffer system uses an inverter (KGS SS120) to the 28VDC (20A CB) of the aircraft to 115VAC, this is necessary for the external components and the Thermo 43i TLE sensor. For the different components other power conversions are necessary (115VAC to 24, 19, 12, 5 VAC). The total theoretic power consumption of the sniffer system and the external components (Laptop + Thunderbolt Dock) is 18 A. The actual power consumption of the sniffer system is 8-11 A, this means that there is still a potential of 8 A available for future modifications. An overview of the internal power distribution is displayed in Figure 6. Following power converters are installed:

- Inverter KGS SS120 (28 VDC to 115 VAC 60 Hz) to power converters and 80 mm fans (10.3A ~50A@28V)
- Traco Power TMP 15105C 100-240VAC to 5 VDC (3 A ~0.5A@28VAC)
  18. Ethernet hub
  19. RS232 to Ethernet
  20. 40mm fans
- Traco Power TMP 30112C 100-240VAC to 12 VDC (2.5 A ~1.1A@28VAC)
  21. AIS+GPS
  22. ARINC board
- Traco Power TMP 30124C 100-240VAC to 24 VDC (1.25 A ~1.1A@28VAC)
  23. Licor
  24. Bronkhorst regulators
- Unknown manufacturer 115-19V (3.4 A ~2.3A@24VAC), located next to the LOG PC
  25. Log Computer
- Thermo power converter 115-24 V (166 watt – 7 A ~6A@28VAC) located beside the motherboard
  26. Thermo
- EPC power supply (26V)
  27. Air pump 1 (KNF 838.1-2)
  28. Air pump 2 (KNF 838.1

4 circuit breakers are available on the casing of the sniffer:

- CB 1 (5A): External 115V connector (J211) for NO_x sensor
- CB 2 (5A): Traco power converters, air pump (1&2) and MUMM_LOG_PC
- CB 3 (5A): NO_x air pump (KNF N 022 ATE)

- CB 4 (5A): Thermo 43i TLE

Following internal fuses are included:

- Fuse 1: Inverter 50 A
- Fuse 2: LICOR 2.5A

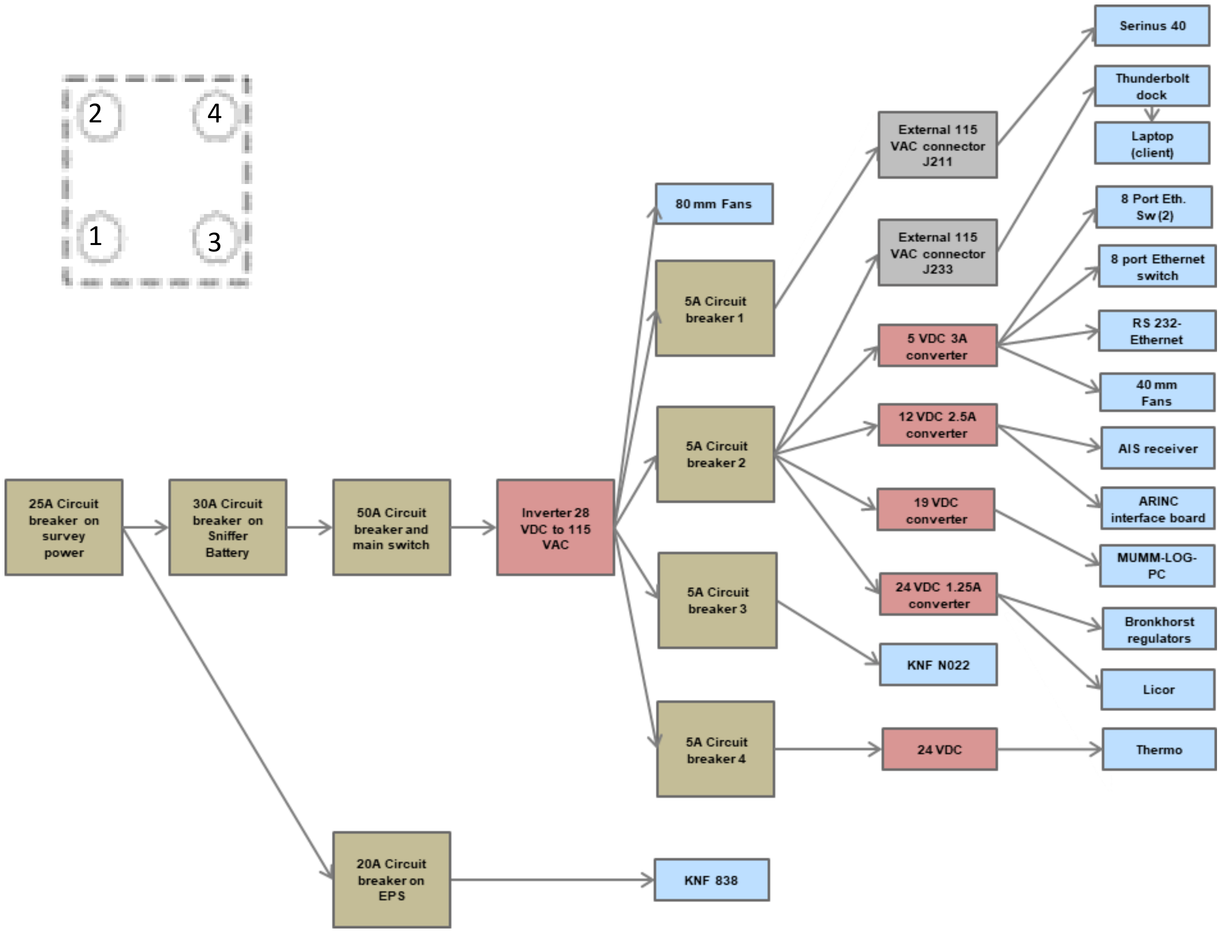


Figure 49 Overview power distribution and circuit breakers inside the sniffer sensor system

1.3.6 Fans

2 types of fans are used, 3 x 80 mm fans (NMB) running on 115 VAC on the backside and 12 x 40 mm fans (Sunon) running on 5 VDC on the front side (installed in 3 blocks of 4 fans).

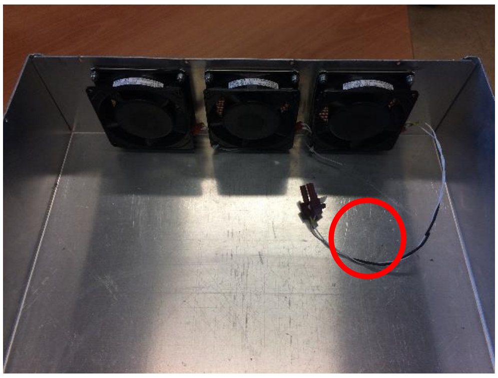


Figure 50 Cooling fans (115 VAC) with power connector (red)

1.3.7 Casing

The sniffer sensor is divided in 2 main parts, a bottom part and top part that are separated by an aluminum inner frame. All components and wiring are attached to this inner frame. Different openings are made in the internal frame to connect components between the top and bottom part. The bottom and top part are closed from the outside with large aluminum covers, that contain almost the full exterior of the sniffer sensor (except the connector panel). The fans are the only sensor components attached to the covers, all fans are covered with fine aluminum mesh to avoid EM interference. The top and bottom covers are attached to the internal frame with M3x10 TX10 screws. Most components and wiring are attached to the internal frame with M5 locknuts. The available space in the sensor for future sensors is 60x12x25 (LxWxH). All connectors used on the sniffer are MIL standard connectors (EMC shielded) and are attached to the sniffer casing using Allen hex screws size M2.5x10

1.4. Particle filters

Two fine particle filters are installed in a box outside of the sniffer system (see Figure 51 and Figure 52). The very fine pore size (1µm) prevents water and particles to enter the system. The 2 filters installed in a parallel configuration to allow for a maximum flow. The box is installed between the air inlet and the sniffer system. The specifications of the filters are:

- Manufacturer: PAL
- Type: ACRO 4003 PTFE
- Size: 50 mm
- Pore size: 1µm
- Connection: 1/8 in. MNPT (with Teflon tape)

A valve is installed before the filter inlet to switch between ground (GND) and in-air (AIR) operations. In GND mode, the air inlet comes from inside the cabin and passes through a carbon and Purafil filter to avoid contamination. In AIR mode the air flow comes straight from the Pitot tube.

Figure 51 Arco PALL filter (left filter shows filter after 6 months of use)

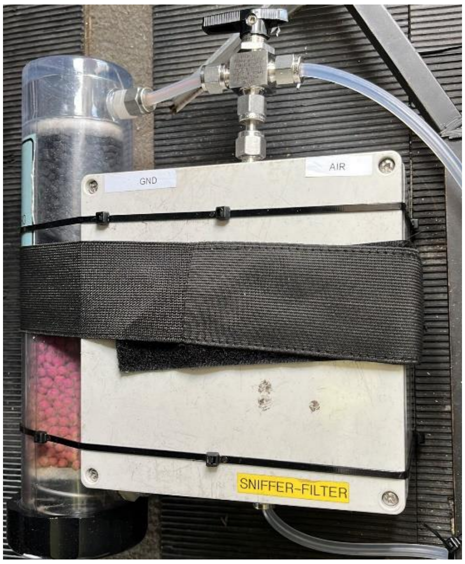


Figure 52 Figure 20 Filter box containing the particle filters and valve to switch between ground (GND) and in-air (AIR) operations

1.5. Client stations

The sniffer sensor system is a network based system. This means that all sensor data is gathered on the internal LOG-PC and made available for different IGPS software installations on client stations. The client stations are connected with the sniffer sensor via 2 Ethernet connections. 2 clients are used in the aircraft. One on the Mission Management Unit from Optimare on a Virtual Machine and on each of the operator laptops.

1.5.1 Operator laptop client stations

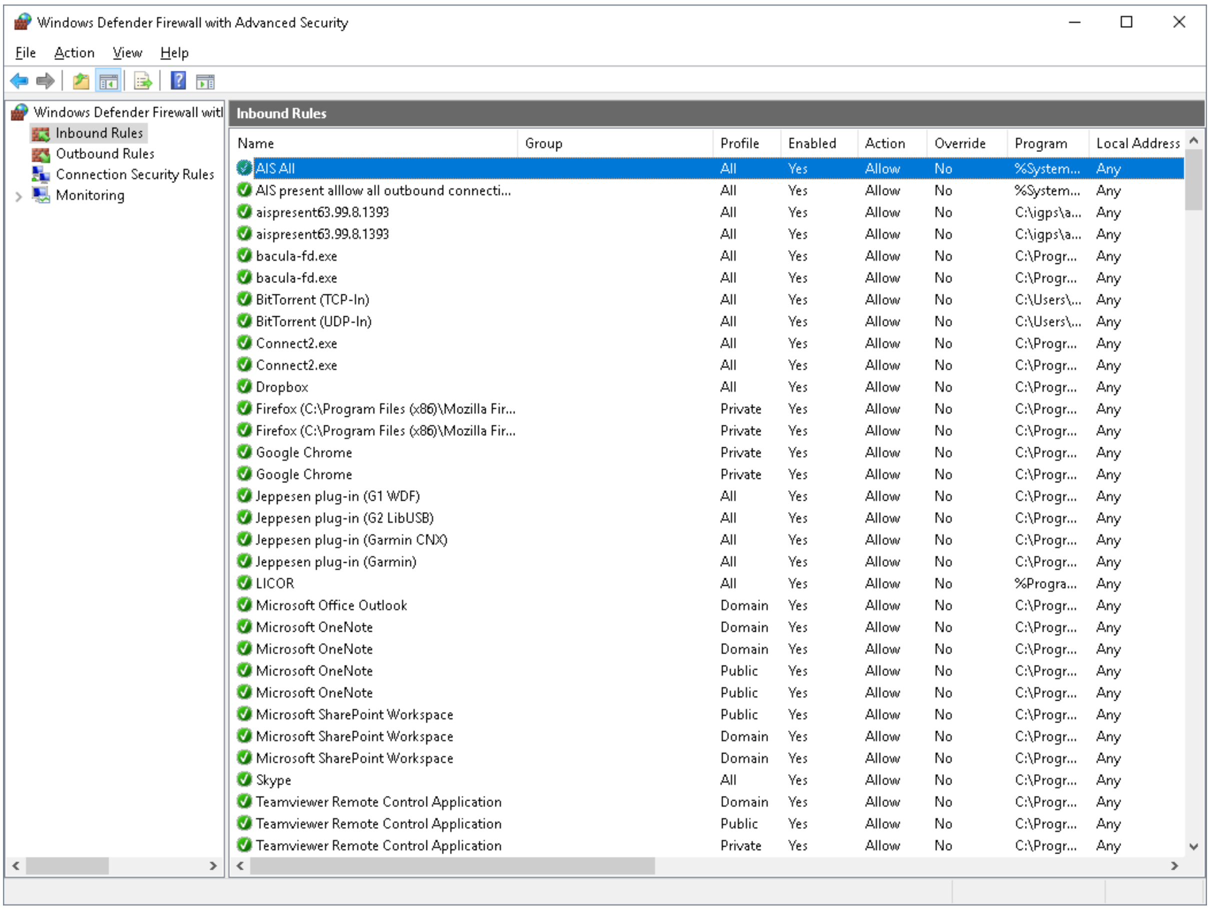
4 Dell Latitude 5420 stations have been acquired to be used during sniffer flight with following general specifications:

- Processor: i7-1165G7 CPU @ 2.8 GHz
- RAM: 32GB
- System: 64bit Windows 10Pro

In principle most off the shelves laptops would be suitable to run the IGPS software, but some requirements improve significantly operational efficiency.

- A touchscreen makes it easy to manipulate the software during flight.
- A 1TB Solid State Drive is more reliable in harsh environments (vibration).
- A fast processor and video card provide fast visualization and calculations of ship plumes and FSC.
- An illuminated keyboard allows to use the Laptops during low light conditions.
- A Thunderbolt connection use both power and Ethernet over 1 cable.
- A powerful battery to last during the whole flight.

To enable the connection from the Laptop to the sniffer sensor the firewall settings have been adjusted. This is generally requested during first opening of the IGPS software (AISPresent.exe) but in a few situations it was needed to do this manual, by adding a new in-bound and a new out-bound rule for the AISPresent.exe program in the firewall advanced settings (all connections are allowed).



Name	Group	Profile	Enabled	Action	Override	Program	Local Address
AIS All		All	Yes	Allow	No	%System...	Any
AIS present alllow all outbound connecti...		All	Yes	Allow	No	%System...	Any
aispresent63.99.8.1393		All	Yes	Allow	No	C:\igps\a...	Any
aispresent63.99.8.1393		All	Yes	Allow	No	C:\igps\a...	Any
bacula-fd.exe		All	Yes	Allow	No	C:\Progr...	Any
bacula-fd.exe		All	Yes	Allow	No	C:\Progr...	Any
BitTorrent (TCP-In)		All	Yes	Allow	No	C:\Users\...	Any
BitTorrent (UDP-In)		All	Yes	Allow	No	C:\Users\...	Any
Connect2.exe		All	Yes	Allow	No	C:\Progr...	Any
Connect2.exe		All	Yes	Allow	No	C:\Progr...	Any
Dropbox		All	Yes	Allow	No	C:\Progr...	Any
Firefox (C:\Program Files (x86)\Mozilla Fir...		Private	Yes	Allow	No	C:\Progr...	Any
Firefox (C:\Program Files (x86)\Mozilla Fir...		Private	Yes	Allow	No	C:\Progr...	Any
Google Chrome		Private	Yes	Allow	No	C:\Progr...	Any
Google Chrome		Private	Yes	Allow	No	C:\Progr...	Any
Jeppesen plug-in (G1 WDF)		All	Yes	Allow	No	C:\Progr...	Any
Jeppesen plug-in (G2 LibUSB)		All	Yes	Allow	No	C:\Progr...	Any
Jeppesen plug-in (Garmin CNX)		All	Yes	Allow	No	C:\Progr...	Any
Jeppesen plug-in (Garmin)		All	Yes	Allow	No	C:\Progr...	Any
LICOR		All	Yes	Allow	No	%Progra...	Any
Microsoft Office Outlook		Domain	Yes	Allow	No	C:\Progr...	Any
Microsoft OneNote		Domain	Yes	Allow	No	C:\Progr...	Any
Microsoft OneNote		Domain	Yes	Allow	No	C:\Progr...	Any
Microsoft OneNote		Public	Yes	Allow	No	C:\Progr...	Any
Microsoft OneNote		Public	Yes	Allow	No	C:\Progr...	Any
Microsoft SharePoint Workspace		Public	Yes	Allow	No	C:\Progr...	Any
Microsoft SharePoint Workspace		Domain	Yes	Allow	No	C:\Progr...	Any
Microsoft SharePoint Workspace		Domain	Yes	Allow	No	C:\Progr...	Any
Skype		All	Yes	Allow	No	C:\Progr...	Any
Teamviewer Remote Control Application		Domain	Yes	Allow	No	C:\Progr...	Any
Teamviewer Remote Control Application		Public	Yes	Allow	No	C:\Progr...	Any
Teamviewer Remote Control Application		Private	Yes	Allow	No	C:\Progr...	Any

Figure 53 Advanced firewall settings

For operational and safety related reasons the operator laptops are mounted inside the aircraft using a laptop mount (Ram Mount Model: RAM-VBD-128-SW1).

Figure 54 RAM mount for installation operator laptop

1.5.2 MMU client station

The MMU is the main console in the aircraft used for the Medusa system. The MMU runs on a tailored Open Suse Linux Platform and is therefore not suited for the installation of the IGPS software. A Virtual Machine (VM Player) with a Windows XP installation is installed on the MMU to allow to run IGPS on the console. An Ethernet connection from the VM to the Sniffer sensor is installed from J221 to the central Ethernet hub inside the console.

The VM main settings are: 2GB RAM, 2 Processors, 60 GB virtual Hard Drive and 3 virtual Ethernet Network Adapters (bridged to host).

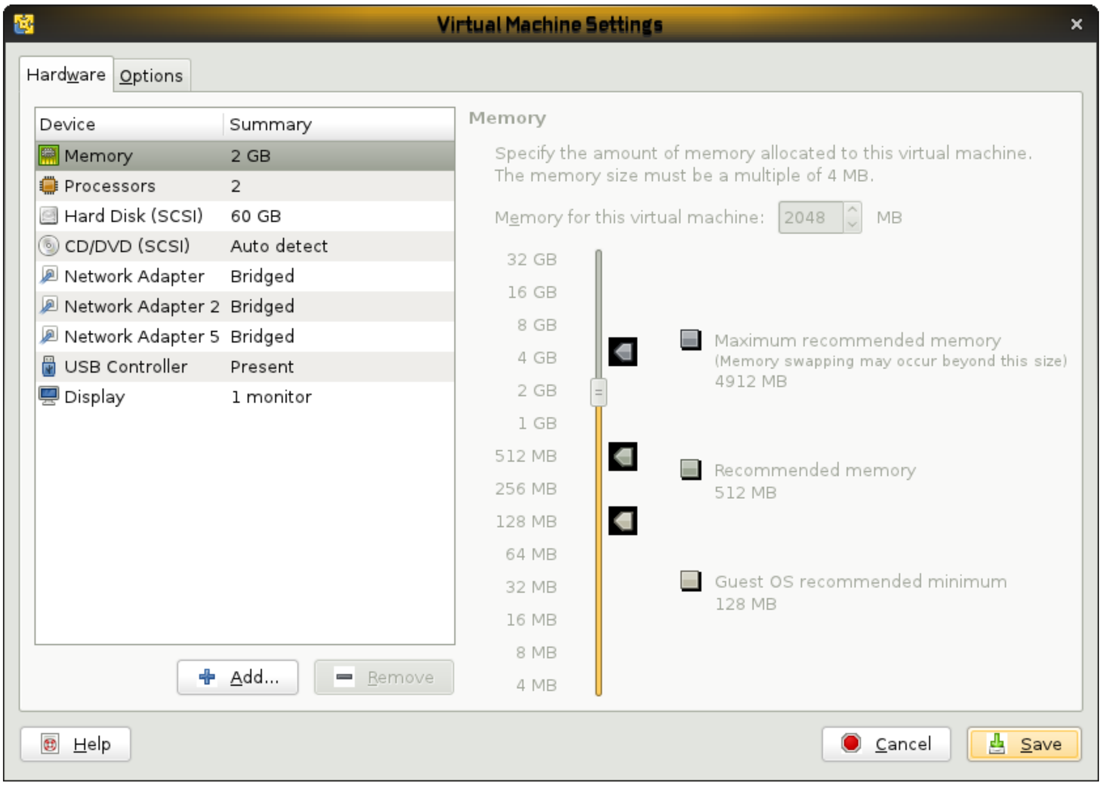
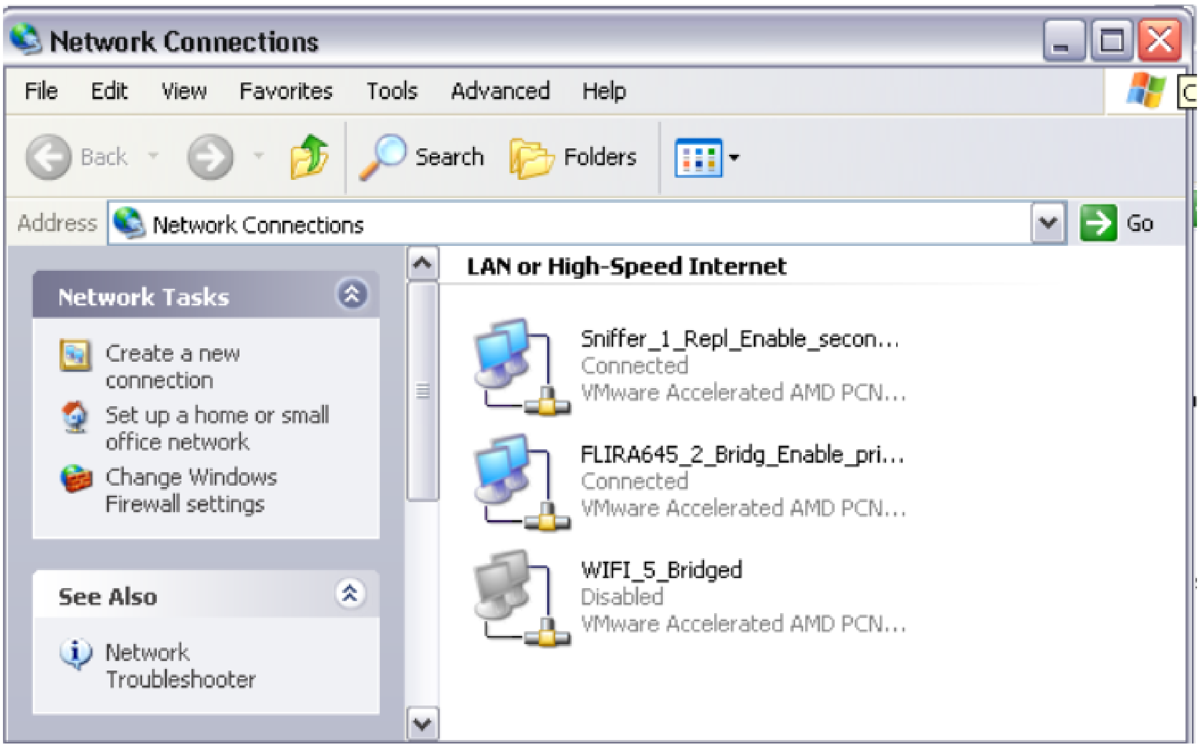
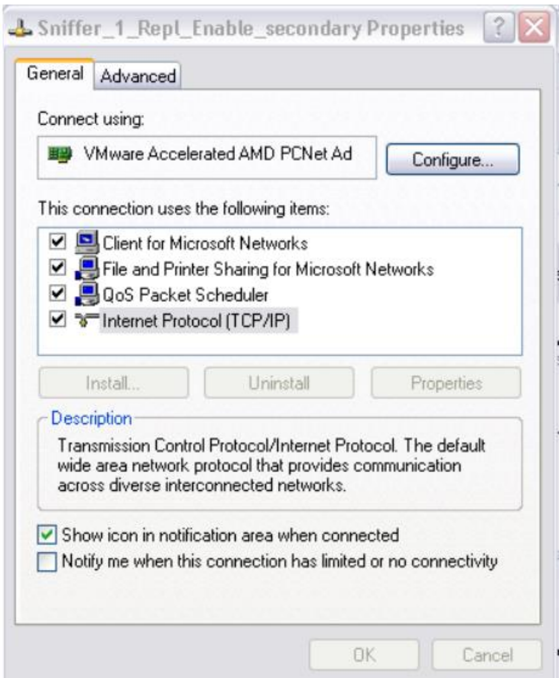


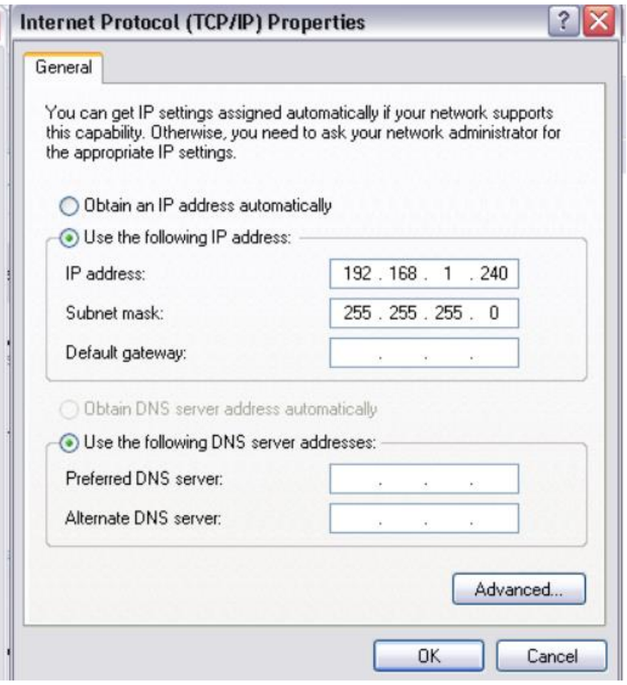
Figure 55 2 VM settings on the MMU

The network adaptors are used for the Wifi connection, the FLIR camera and the Sniffer sensor. The IP addresses for these 3 virtual Network adapters can be changed via the Network settings in Windows XP on the VM (see). Use following IP addresses for the network adapters:

- FLIR Camera:
- Wifi: Automatic
- Sniffer: 192.168.1.240 (Subnetmask 255.255.255.1)


Network Connections
File Edit View Favorites Tools Advanced Help
Back Search Folders
Address Network Connections Go
Network Tasks
Create a new connection
Set up a home or small office network
Change Windows Firewall settings
See Also
Network Troubleshooter
LAN or High-Speed Internet
Sniffer_1_Repl_Enable_secon...
Connected
VMware Accelerated AMD PCN...
FLIRA645_2_Bridg_Enable_pri...
Connected
VMware Accelerated AMD PCN...
WIFI_5_Bridged
Disabled
VMware Accelerated AMD PCN...


Sniffer_1_Repl_Enable_secondary Properties
General Advanced
Connect using:
VMware Accelerated AMD PCNet Ad
Configure...
This connection uses the following items:
Client for Microsoft Networks
File and Printer Sharing for Microsoft Networks
QoS Packet Scheduler
Internet Protocol (TCP/IP)
Install... Uninstall Properties
Description
Transmission Control Protocol/Internet Protocol. The default wide area network protocol that provides communication across diverse interconnected networks.
Show icon in notification area when connected
Notify me when this connection has limited or no connectivity
OK Cancel


Internet Protocol (TCP/IP) Properties
General
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.
Obtain an IP address automatically
Use the following IP address:
IP address: 192 . 168 . 1 . 240
Subnet mask: 255 . 255 . 255 . 0
Default gateway:
Obtain DNS server address automatically
Use the following DNS server addresses:
Preferred DNS server:
Alternate DNS server:
Advanced...
OK Cancel

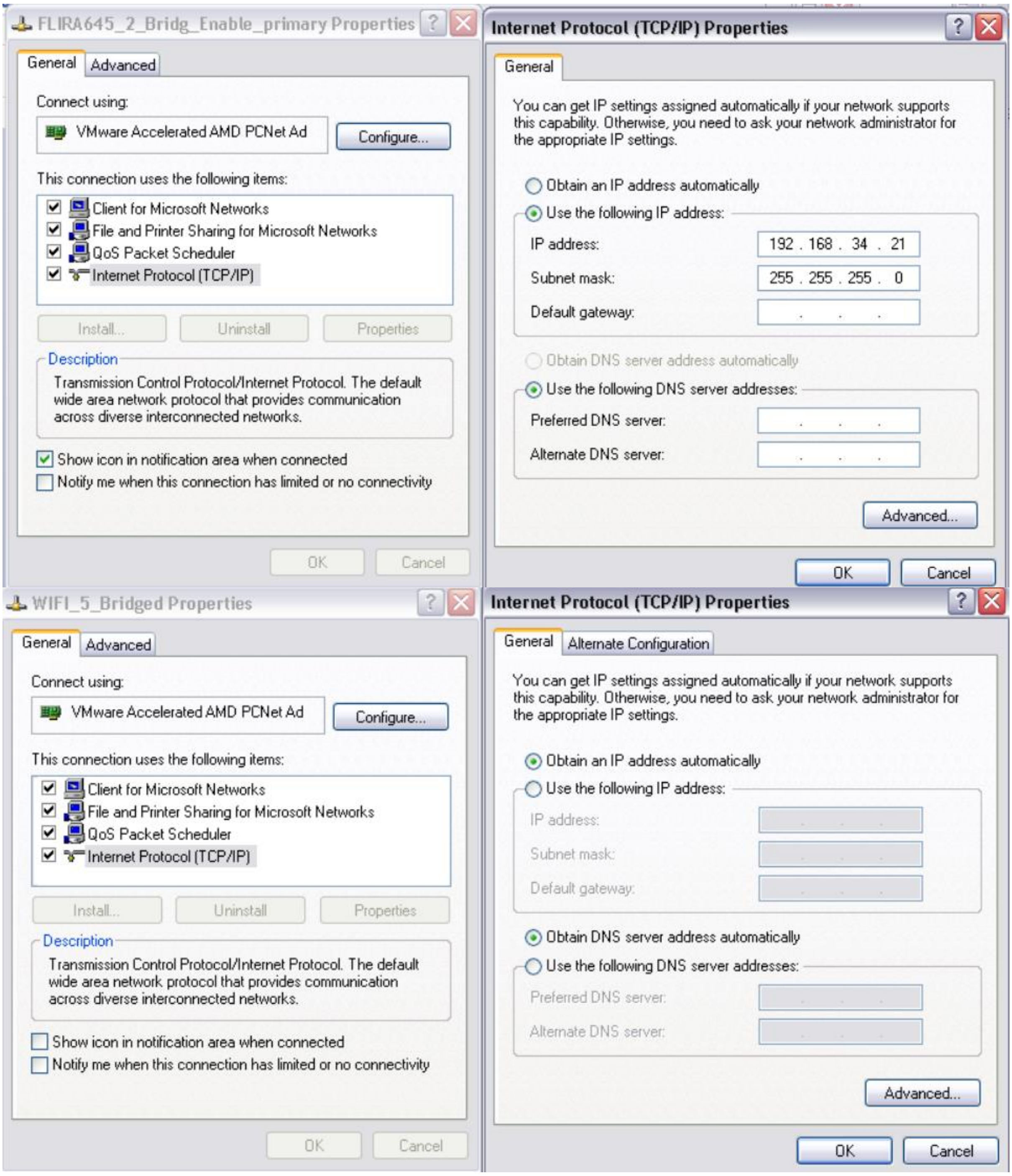


Figure 56 Network settings VM for Ethernet adapters 1 (Sniffer), 2 (FLIR) and 5 (WIFI)

Note: Because of an IP address conflict with the Sniffer, the WiFi connection can currently not be used together with the sniffer sensor (network adapter for WiFi must be disabled when operating the sniffer), in case the FLIR camera is required the sniffer network adapter must be disabled first After connecting the FLIR camera, the sniffer network adapter can be re-enabled.

The IGPS software is installed on the “C:” drive of this VM XP distribution. The firewall has been deactivated for the IGPS software. TeamViewer V12 has been installed on the VM to enable a remote desktop connection to the MUMM_LOG_PC. To allow sharing of folders with the console the shared folders must be activated in the Virtual Machine Settings and VMWare tools must be installed.

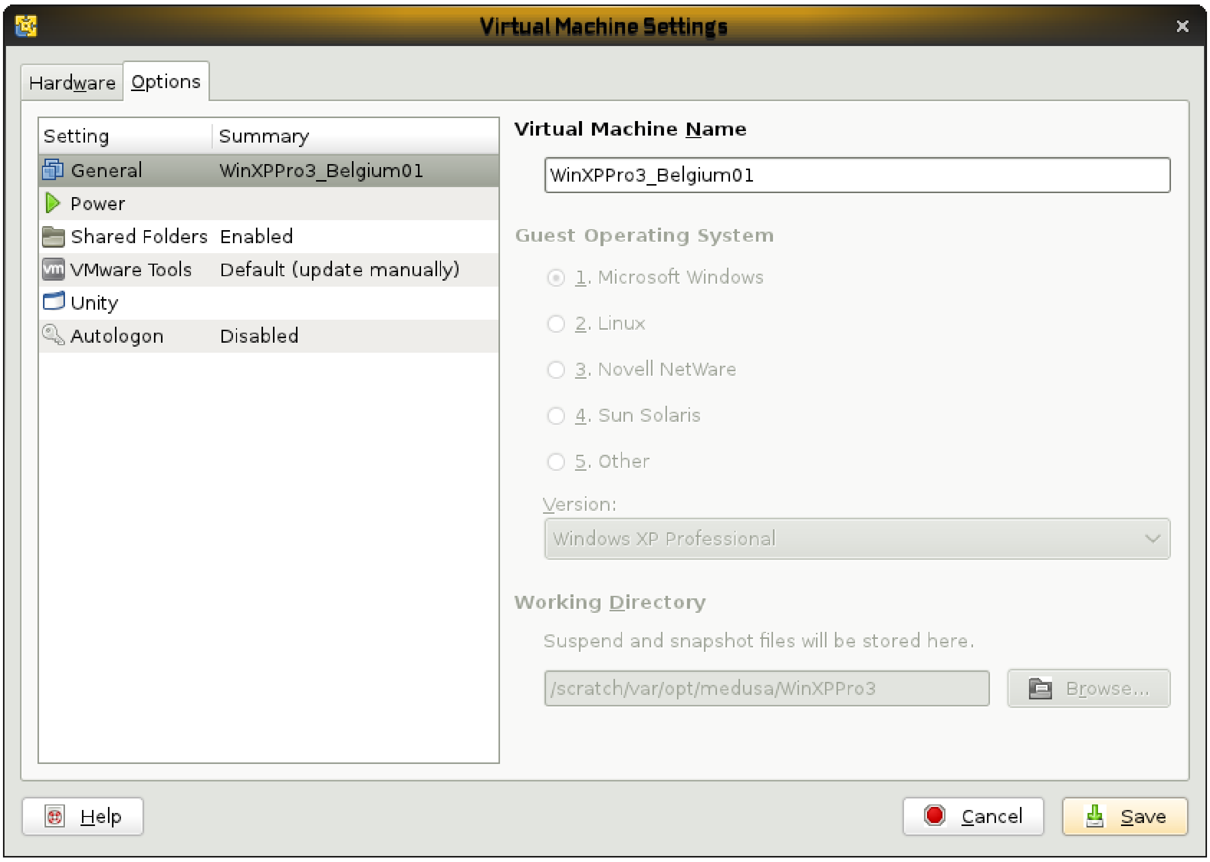


Figure 57 VM settings on the MMU shared folders and VMware tool

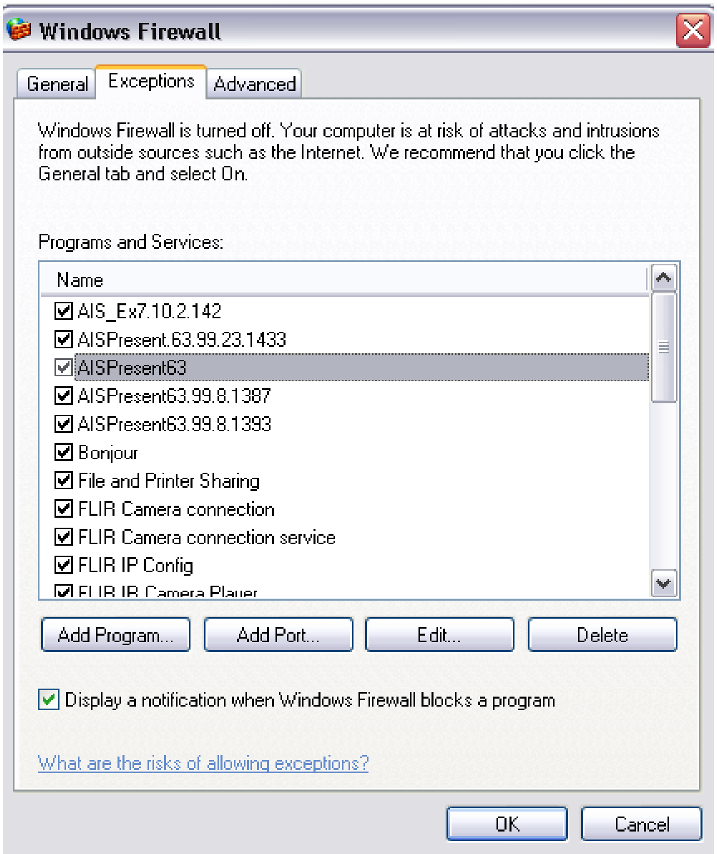


Figure 58 Firewall settings on VM

An additional USB to VGA adapter is installed on the VM (Startech USB to VGA External Video Card). This allows the presentation of the VM display (SNF view of the AISPresent.exe) to the cockpit display and G600 (Video 2). To connect the VGA adapter to the VM player, this device needs to be connected thorough Removable Devices>>Magic air. The remote monitor can be activated via the Magic Air button in the task bar.

Figure 59 USB to VGA converter

1.5.3 IGPS software

The IGPS folder is installed on the "C:" drives of the operator laptops and are synched by Seafile. This way all operators use the same software version. The different software directories and files are:

- "Charts" Directory: folder with Open source charts of the world
- "Missions-Data" Directory: folder with generated reports of observations
- "MAIL" Directory: not used by SURV
- "AIS_EX8.exe" program: tool used for extraction of TCP-LOG files
- "AISPresent.exe" program: main software program used in flight and during calibrations
- "IPGSAna44.exe" program: software for post flight analysis (extraction required)
- "AISPresent.ini": this is the settings file for AIS present (can be read and edited using Notepad)
- "IP-configuration-SURV.txt" file: this document contains the used IP addresses for the different clients
- "Emissiondata_xxx.txt" files: are generated by the different clients (ODN-WVR, ODN-KS, ..) and contain the FSC measurements
- "Mail_Sniffer_SO2_Man_Meas.csv" file: contains the evaluation (High/Low/Not detected) of the manually marked ships
- "Comments _xxx.txt" contain the stored comments (old comment files are stored in "Comments" directory
- "wakeuplan.txt" file: contains the Mac address of the MUMM_LOG_PC in the sniffer sensor and can be used to wake up by Lan
- "Optical_SO2_Man_Meas.txt" file: not used by SURV
- "STATICSHIPDATA_xxx.txt" file: contains a record of the observed ships per operator
- "MMSI_Date.csv" file: database containing Keel Laying Years and MMSI data for the global fleet
- "Thresholds, BIAS and SFOC-2022.xls" file: reference file containing the SFC calculation tool, thresholds for FSC and NOx, the bias for FSC, this file also contains a conversion for the NOx measurements by using the actual SFC
- "borlndmm.dll", "cc32230.dll", "cc32230mt.dll", "Fetchlog.txt", "Logfile.txt", "Memo1-1.txt": are other additions files

The operational use of the software is described in Section 1 of the Sniffer QMS. The data storage, data processing, … is described in Section 3.

1.6. Pneumatics

1.6.1 Swagelok fittings

For all connections, both internal and external connections, Swagelok connections are used. For tubing, Nylon (NY), Teflon or PVC tubing can be used. For the permanent tube connections stainless steel fittings (SS) are used (fitting with nut, front and back ferrule, see Figure 60). The main size for tubing and tube connections is 1/4" although the pitot-tube and exhaust uses 3/8" connections and tubing, the connection toward the NOx is done in 1/8" to minimize the delay time between the NO_x signal and the CO_2, signal.

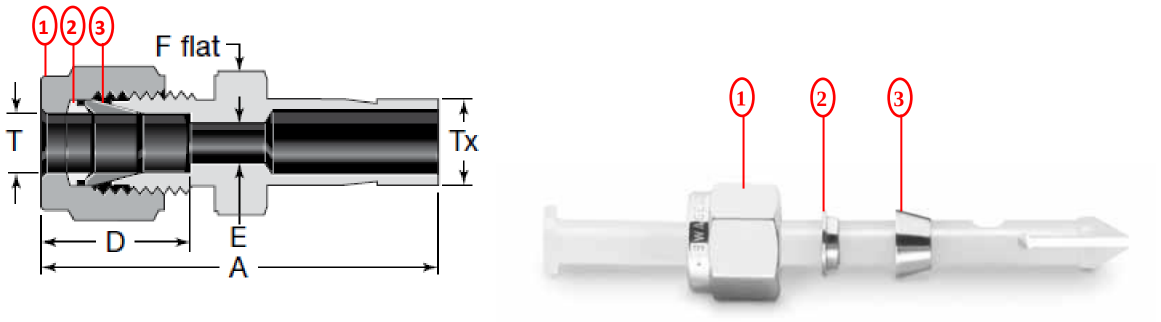


Figure 60 Swagelok fitting with nut (1), front (3) and back (2) ferrule (Swagelok, 2016)

1.6.2 Pitot tube and exhaust

The sniffer pitot-tube or sample probe consist of a Swagelok bulkhead connector (SS-600-61-4) to pass through the fuselage of the aircraft (see Figure 61), with on the inside a 1/4" connection connected with a port connector (SS-401-PC) by a 90° turn (SS-400-9) and on the other side a 3/8" connection connected to 10 cm 3/8 stainless steel tubing 316/316L 0.65in thickness (SS-T6-S-065-20). The exhaust tube is similar bulkhead connect but with both sides in 3/8" (SS-600-61) and without 3/8" Stainless steel tube extension.

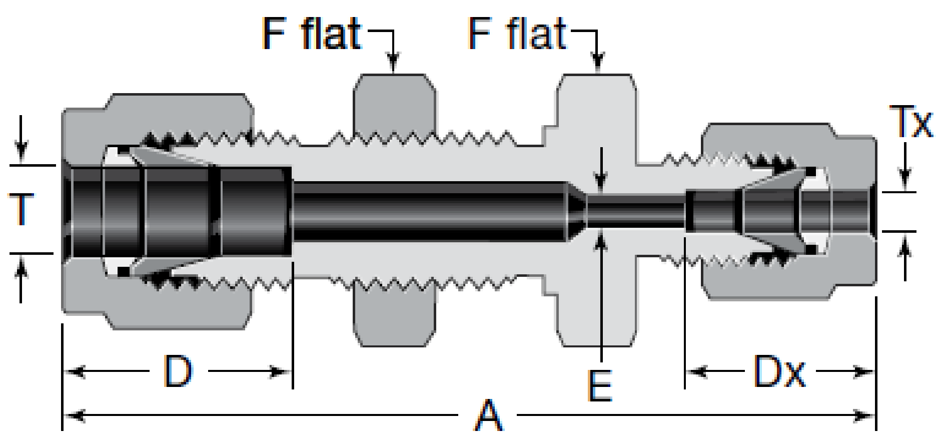


Figure 61 Bulkhead connector used for the pitot-tube to pass through the aircraft fuselage

1.6.3 Reference gas cylinder equipment

The reference gas cylinders used during the calibration are equipped with a pressure regulator, flow-meter (volume meter) and rotameter (see Figure 62) with following specifications:

- Regulator CO_2: HBS 200-3-2,5 (Airliquide): 200 to 0.1-3 bar (B4 or DIN 6 connection)
- Regulator SO_2/NO: HBSI 200-1-2 (Airliquide): 200 to 0.05-1 bar (B8 or DIN 1 connection)
- Volume-meter CO_2: Dynaval Azote (Airliquide), 0-15 l/min
- Volume-meter SO_2/NO: Millimite.S_200-0,02 AN (0.02 Kv)
- Rotameter: Brooks 2510 A 2A13 S N VT (Jadition), 0-1 l/min

A different regulator is used for CO_2 and SO_2/NO cylinders (opposite thread for SO_2/NO). The volume meter is connected to the regulator output. The output from the volume meter is split with a Swagelok Tee-connector (SS-400-3), one side can be connected with the flexible hosing and the other side is connected with a rotameter to measure the overflow during calibrations. The outlet of the rotameter is open to the atmosphere. An additional Swagelok toggle valve (SS-1GS4) is installed between the volume-meter and the T-connector, this enables a quick flushing of the regulator.

Figure 62 Installation of reference gas cylinders on chart, every cylinder is equipped with regulator (1), volume-meter (2) and rotameter (3). The gas cylinders are attached to the chart with a heavy duty strap

1.7. External signal wiring

A detailed description of all connection including signal wiring to and from the sniffer is available in **Annex B** - Interface Connection Documentation. The Sniffer sensor is connected to the aircraft navigation instrumentation (Garmin GTN-650) using the Arinc protocol information on wind and positioning is provided to the Sniffer sensor.

The sniffer sensor works in a network based structure, the sensor is equipped with an internal computer, but all sensor data can be consulted on a network. Two Ethernet connections area available on the sniffer sensor, one is connected to the Optimare Mission Computer, the other is connected to an ethernet hub, which connects to 1) a Thunderbolt docking station (Startech) that can be used to connect with operator laptops and 2) with the NO_x sensor. The available IP addresses for client stations to connect to the sniffer sensor are available in Table 1, the subnet mask is 255.255.255.1. More information is available in Section 3 of the SMQS on how to change the IP addresses of the client stations.

Table 8 IP addresses for external connection to the sniffer sensor

IP addresses	User
192.168.1.230 -239	available
192.168.1.240	Console via VM
192.168.1.241	PC Ward via Thunderbolt
192.168.1.242	PC Kobe via Thunderbolt
192.168.1.243	PC Annelore via Thunderbolt
192.168.1.244	PC Benjamin via Thunderbolt
192.168.1.245	PC Ward via cable
192.168.1.246	PC Kobe via cable
192.168.1.247	PC Annelore via cable
192.168.1.249	PC Benjamin via cable

1.8. Power distribution to the sniffer

A detailed description of the power distribution from and to the sniffer is available in Annex B - Interface Connection Documentation. The sniffer is equipped with a master power switch and a remote switch (via J211 pin E see Annex B), the master power switch is best left switched on (upwards) the remote switch is located at the operator intercom panel. A 20A circuit breaker has been installed in the cockpit an additional 20A circuit breaker has been installed on the output of the emergency battery; pull both circuit breakers in case of long-term inactivity or in case of emergency.

1.8.1 Aircraft power

The sniffer is powered from the “Utilities” bus a, relay connected to the “Survey power” is powering the sniffer. A connector for the powering of the sniffer is installed in the ASP connector panel on the left side of the aircraft, behind the sniffer (ASP-CON-07). See Table 9 for the basic specifications or see wiring diagram OO-MMM ASP in Annex B - Interface Connection Documentation for more detailed information. The original fuse of 20 A was increased to 25 A to include the NO_x sensor.

Table 9 Connection to the aircraft power supply

	Description	Manufacturer
Connector Type Chasis	62GB-12E14-02SN	Amphenol
Contact Type Chasis	FEMALE	Amphenol
Shell Size Chasis	14	Amphenol
Connector Type Cable end	62GB-56TG14-02PN	Amphenol
Contact Type Cable end	MALE	Amphenol
Shell Size Cable end	14	Amphenol
Strain Relief	BS1SRN14999XY	Amphenol

PIN	Conductor Type	Signal Name	Signal Logic / Load (A)
A	AWG 12	+ 28 VDC CB 27 Console	Max 20 A
B	AWG 12	GROUND	Max 20 A

CB 27 20A Instrument Panel Klixon pn 7277-2-20

1.8.2 115 VC

Two 115VC (5 Amp) power sockets are available one is used for the portable computers, the external ethernet hub and the Thunderbolt docking station and the other one is used for the NO_x sensor.

1.8.3 Emergency power

An external removable emergency battery (consisting of 2 Sonnenshein A512 /10 S - 12V 10aH units) is installed between the ASP connector panel and the sniffer. The battery is able to take-over power interruptions up to 10min (<5 min in practice). The battery is attached to the left side of the console with 4 SS bolts (M5X40). A switch has been added to allow the power switching between Aircraft power supply (switch to the nose of the aircraft) and Ground Power supply (switch to the back of the aircraft), or in neutral mode (middle position). A led has also been added to notify to the operator if the sniffer is powered, when the led is on power towards the sniffer is secured, when the led is off, power to the sniffer is only provided by the battery (will be depleted <5 min). To improve the battery duration an additional Mid Continent MD835 (formerly TS835) EPS system is added in the power supply system to allow for longer power shortages.

Tabel 1 Properties of the external battery units

Type	Type	Nom volt	Nom. Cap: (C20) to 1.75vpc	Discharge current (I20)mA	Max. load appr. A	Max. current 5 sec. appr. A	Weight appr. kg	Length in mm	Width in mm	Height in mm	Connection type
795525	A 512/10 S	12	10.0	500	80	300	4.1	152.0	98.0	98.4	Faston terminal 4.8
TS835	MD835-1	20-32	4.5	-	20	-	2.16	322.58	58.42	78.74	ITT Connaon DPXB-13-33S-0001 In 1/4 ATR rack

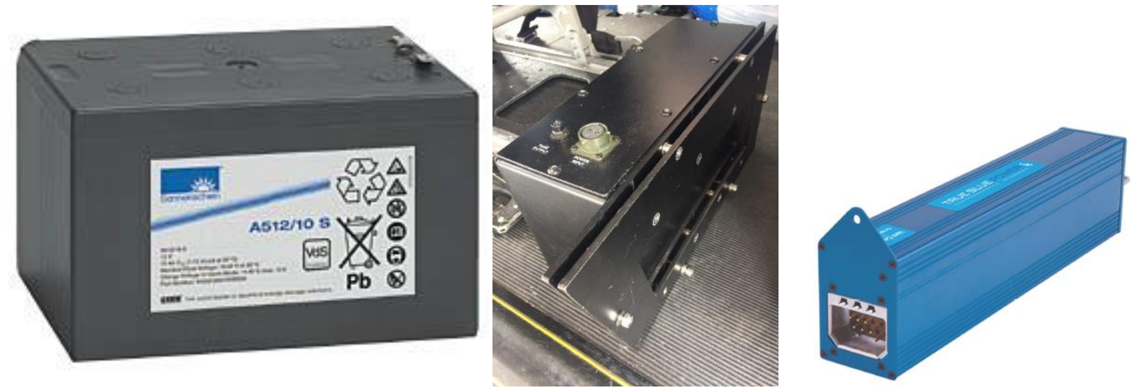


Figure 63 Sonnenschein A512/10 S Dryfit 12V Lead Acid Battery (2x) used in the emergency power battery

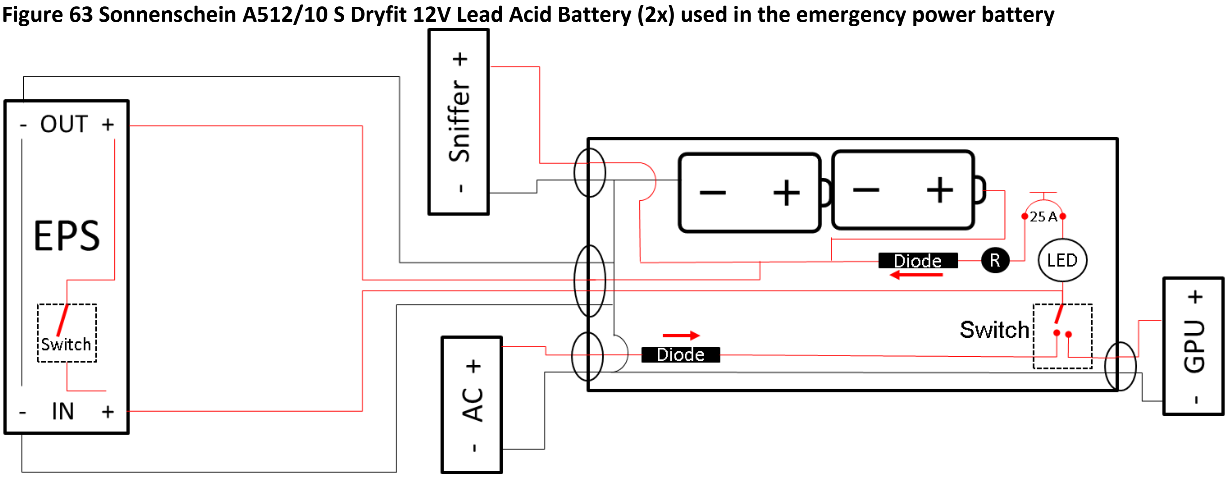


Figure 64 Emergency battery system, with 2 12VDC batteries and EPS system

1.8.4 GPU

The Sniffer can be powered on ground by using a GPU (Startpac 53050) connected to the AC external power bus (See Figure 3). An additional connector (with 25A CB) is installed on the GPU to power the sniffer sensor independent from the AC power supply (connection to the external battery) or outside of the AC (connection straight to the Sniffer sensor 28V input connector). The used connector is the same as the one used for ASP-CON-07A for the AC power to the sniffer (62G-12E14-02SN), therefor no other cabling is required. Note that this GPU cannot be used to start the aircraft engines. A power meter is added to allow the operator to evaluated the current power use (on the external connection)

Note: Always connect the GPU to the sniffer/battery/AC first before powering on the GPU.

- Voltage 28.5 VDC (50A)
- AC input is universal 90-240 Volts.
- Over current, voltage and temperature protection
- Forced air-cooling
- 4.5 kg with aircraft cable
- DIMENSIONS : L 36cm x W 13cm x H 14 cm
- CE Certified
- Equipped with Amphenol 62G-12E14-02S connector (pin A: +28V, Pin B: ground)
- Equipped with RS power meter (0-50A) on additional connector

Figure 65 Start Pac GPU used for powering the aircraft systems on ground, with addition connector and power meter

1.9. Sniffer equipment rack

The sniffer sensor is installed in a 19 inch equipment rack that also holds the Terma SLAR transceiver (see Figure 5) both sniffer and SLAR are attached with 3/8 bolts (Sniffer: AN3-4A, SLAR: AN3-5A). The rack is installed behind the pilot seat. The SLAR is attached to the rack with 4 bolts in the front plate (RH side of the AC). The sniffer sensor is fixed in the rack with one front side bracket (RH side of AC), one backside bracket (LH side of AC) and 2 top brackets. The side brackets are attached to the equipment rack with 2 bolts on each side, the top brackets are attached to the sniffer rack with 1 bolt on each side. The equipment rack is mounted to the remote sensing base plate with 8 bolts. This baseplate also supports the console of the Mission Management system. The base plate is attached with 8 custom made bolts (7/16”) to the airframe of the aircraft by using the slots used for the passenger seats (row 3-5).

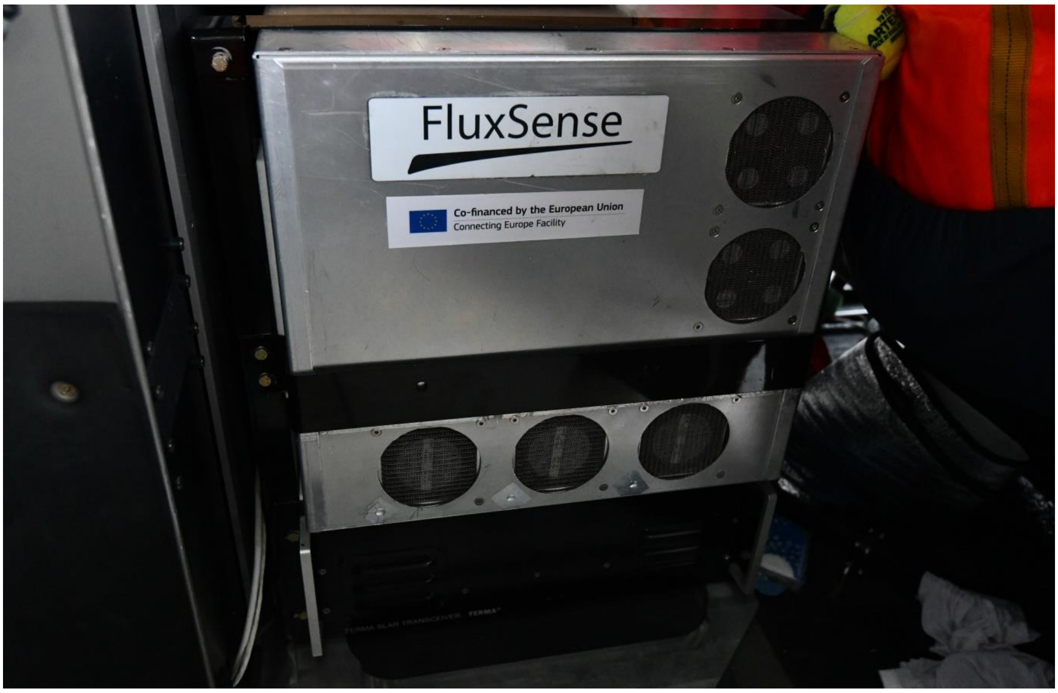


Figure 66 Sniffer 19” Equipment rack

CHAPTER 2. INTERVENTION AND SERVICING SCHEME

The sniffer sensor system intervention and servicing scheme is in provided in Table 10. A centralized maintenance intervention archive is available in the LOG sheet in the SQMS-Follow-up.xlsx file under the SURV Seafile directory: "5-Instrumentation/05-FluxSense_Sniffer/QMS/QA_Follow-up" every executed intervention or service operation whether or not included in the intervention scheme is logged into this system for record keeping. In case of malfunctioning, the issue should be reported in the comprehensive SURV issue tracking system "OO-MMM issue tracker.xlsx" which can be found under the SURV Seafile directory: "06-Issue-Tracker".

Table 10 Intervention scheme for the sniffer sensor system on board of the OO-MMM aircraft, "Recurrence Time" and "Additional service indicators" determine when a service intervention is requested *(use "ctrl+ click" on "Ref. Chapter" to navigate to the required section)*

Ref. Chapter	Description	Intervention Type	Recurrence	Additional service indicators
		Daily		
Chapter 3	Software calibration	Calibration	Before every mission	-after maintenance or hardware calibration **indicated in SQMS-Follow-up.xlsx CO2/SO2 sheet**
Chapter 4	NO_x Hardware calibration	Calibration	Before every mission	-after maintenance **indicated in SQMS-Follow-up.xlsx CO2/SO2 sheet**
		Monthly		
Chapter 4 4.1	CO2 Hardware calibration	Calibration	1 month	Optional: before every flight (before software calibration) -SW CO2 zero is outside -3<offset<10 -If SW k outside 0.6<k<1.5 - After Reference gas calibration **indicated in SQMS-Follow-up.xlsx CO2 sheet**
Chapter 4 4.2	SO2 Hardware calibration	Calibration	1 month	-SW SO2 zero is outside -5<offset<20 -If k outside 0.6<k<1.5 - If drift of more than 10% observed on SO2 reference gas calibration **indicated in SQMS-Follow-up.xlsx SO2 sheet**
		Seasonal - 4 Months		
Chapter 5 5.5	Active SO2 reference gas cylinder calibration	Calibration	4 months	-If HW calibration shows difference of more than 10% -If k outside 0.9<k<1.1

Ref. Chapter	Description	Intervention Type	Recurrence	Additional service indicators
				indicated in SQMS-Follow-up.xlsx SO2 sheet
Chapter 5 5.5	Active NO reference gas cylinder calibration	Calibration	4 months	-If HW calibration shows difference of more than 10% -If k outside 0.9<k<1.1 **indicated in SQMS-Follow-up.xlsx NO sheet**
Chapter 6 6.4.4	Regulators	Leakage test	4 months	After disassembling and reassembling on the reference gas cylinders
Biannual - 6 Months				
Chapter 6 6.2	Filters	Replacement	6 months	When dirty
Chapter 6 6.1.9	Internal tubing and connections	Leakage test	6 months	With non-normal flow or pressure
Chapter 6 6.4.2	External tubing and connections	Leakage test	6 months	After removing sniffer from AC
Chapter 6 6.4.3	Pitot tube	Contamination test (Cleaning) Replacement	6 months	Visual inspection and cleaning (outside) with methanol during washing of the aircraft
Annual – 12 Months				
Chapter 5 5.4	Active CO2 reference gas cylinder calibration	Calibration	12 months	If hardware calibration shows difference of more than 10% on second span **indicated in SQMS-Follow-up.xlsx CO2 sheet**
Chapter 5 5.4	Spare SO2 reference gas cylinder calibration	Calibration	12 months	If active cylinder < 50 bar, next cylinder in line should be calibrated during calibration of the active cylinder **indicated in SQMS-Follow-up.xlsx SO2 sheet**
Chapter 5 5.4	Spare NO reference gas cylinder calibration	Calibration	12 months	If active cylinder < 50 bar, next cylinder in line should be calibrated during calibration of the active cylinder **indicated in SQMS-Follow-up.xlsx NO sheet**
Chapter 6 6.1.5	LOG-PC PC maintenance, updates and backup	Computer maintenance	12 months	Software updates and SSD clone

Ref. Chapter	Description	Intervention Type	Recurrence	Additional service indicators
Chapter 6 6.2	Clients PC maintenance and updates	Computer maintenance	12 months	Software updates
Chapter 6 6.5	External battery capacity test	Battery test / replacement	12 months	Battery test to be executed when external battery fails to power sniffer for less than 15 min In case battery test shows less than 7.5 Ah, battery units need to be replaced
Chapter 6 6.1.8	KNF Air pump (2) Diaphragm replacement	Diaphragm replacement	12 months	External damage, lack of airflow, particles found next to pump (caused by damaged bearing)
Chapter 6 6.1.10	Hydrocarbon tubing leak test + flow test	Leakage test	12 months	Check for leaks in the hydrocarbon kicker tubing, replace particle filter and check the flow though the outer compartment
		Two yearly - 24 Months		
Chapter 5 5.4	Spare CO_2 reference gas cylinder calibration	Calibration	24 months	If active cylinder < 50 bar, next cylinder in line needs to be calibrated during calibration of the active cylinder **indicated in SQMS-Follow-up.xlsx CO2 sheet**
Chapter 6 6.1.1	Licor 7200RS	Factory Cal. Maintenance Change IR source	24 months 72 months	On demand after inspection from Licor
Chapter 6 6.1.2	Thermo 43 I TLE	Maintenance UV source	24 months 5 year	Some components may need to be replaced when malfunctioning. UV source needs to be replaced when lamp intensity is >95% or <50% or when alternating clicking sound is no longer constant (missing clicks)
Chapter 6	Sniffer holistic inspection by FluxSense	Inspection	24 months	Alternating with the CO_2/SO_2 maintenance
		Five yearly - 60 Months		
Chapter 6 6.1.8 **Error! Reference source not found.**	KNF Air pump (1&2)	Diaphragm replacement	60 months	Replace diaphragm and valve plates when pump capacity is decreasing

Ref. Chapter	Description	Intervention Type	Recurrence	Additional service indicators
Chapter 6 6.1.4	Bronkhorst regulators	Inspection / Calibration	60 months	When non-stable pressure/airflow is observed When errors are reported in the diagnostics When LED on top of the instrument is burning red
Chapter 6 6.1.10	Hydrocarbon kicker capillary cleaning	Cleaning	60 months	When airflow though outer compartiment is low or when tales are observed on FSC
		Ad hoc		
Chapter 6 6.1.6	AIS+GPS receiver	Evaluate data reception	Ad hoc	If no longer functional
Chapter 6 6.1.7	Arinc	Inspection / Replacement	Ad hoc	When no Arinc data is received (blue matrix)
Chapter 6 6.1.8	KNF Air pump (1&2)	Inspection/ replacements	Ad hoc	External damage, lack of airflow, particles found next to pump (caused by damaged bearing)
Chapter 6 6.1.10	Internal signal wiring	Inspection	Ad hoc	Replace when damaged
Chapter 6 6.1.12	Internal power distribution	Read out Replacement	Ad hoc	Read-out power distribution and cabling when component failure observed
Chapter 6 6.1.13	Fans	Visual Inspection / cleaning	Ad hoc	During opening of Sniffer casing When scraping sound is heard
Chapter 6 6.1.14	Sniffer casing	Inspection	Ad hoc	When opening sniffer
Chapter 6 6.5	External power	Inspection	Ad hoc	When current is out limits 24V<GPU<30V
Chapter 6 6.6	External signal wiring	Inspection/ replacement	Ad hoc	When connection issues or signal reception
Chapter 6 6.7	Sniffer rack	Inspection	Ad hoc	When removing sniffer from AC

The planning schedule is also available in SQMS-Follow-up.xls under the “Planning” sheet, as soon as a new maintenance operation was performed, the maintenance block should be marked as “v”, the maintenance block will be highlighted green. If the active block is highlighted in yellow, it means the maintenance operation should be performed in the active block, if the maintenance block is red, the maintenance operation has passed its due date and should be performed as soon as possible.

Ref. Chapter	Description	Intervention Type	Recurrence	Additional service indicators	01/01/2018	01/02/2018	01/03/2018	01/04/2018	01/05/2018	01/06/2018	01/07/2018	01/08/2018	01/09/2018	01/10/2018	01/11/2018	01/12/2018
		Daily														
Chapter 3	Software calibration	Calibration	Before every mission	-after maintenance or hardware calibration **indicated in SQMS-Follow-up.xlsx CO2/SO2 sheet**		v	v	v	v	v	x	x	x	x	x	x
		Monthly														
Chapter 4 4.1	CO2 Hardware calibration	Calibration	1 month	Optional: before every flight (before software calibration) -SW CO2 zero is outside -3<offset<10 -If SW k outside 0.6<k<1.5 - After Reference gas calibration **indicated in SQMS-Follow-up.xlsx CO2 sheet**		v	v	v	v	v	x	x	x	x	x	x
Chapter 4 4.2	SO2 Hardware calibration	Calibration	1 month	-SW SO2 zero is outside -5<offset<20 -If k outside 0.6<k<1.5 - If drift of more than 10% observed on SO2 reference gas calibration **indicated in SQMS-Follow-up.xlsx SO2 sheet**	v						x	x	x	x	x	x
		Seasonal - 4 Months														
Chapter 5 5.5	Active SO2 reference gas cylinder calibration	Calibration	4 months	-If HW calibration shows difference of more than 10% -If k outside 0.9<k<1.1 **indicated in SQMS-Follow-up.xlsx SO2 sheet**		v				v				x		
Chapter 6 6.3.4	Regulators	Leakage test	4 months	After disassembling and reassembling on the reference gas cylinders		v				v				x		
		Biannual - 6 Months														
Chapter 6 6.1.3	Filters	Replacement	6 months	When dirty	v						v					
Chapter 6 6.1.9	Internal tubing and connections	Leakage test	6 months	With non-normal flow or pressure	v						v					
Chapter 6 6.3.2	External tubing and connections	Leakage test	6 months	After removing sniffer from AC	v						x					

Figure 67 Planning sheet in SQMS-Follow-up.xls file

CHAPTER 3. SOFTWARE CALIBRATIONS

Note: the sniffer has to be warmed at least 60-120 min. before an SO2 software calibration!

SOP 2.2. To conduct a software calibration

1. When:
    a. Before take-off of the first flight of the day
    b. A software calibration must be performed after every hardware calibration. In case only a hardware calibration was performed, the calibration coefficient should be cleared on the IGPS software.
    c. In case of a 2-day mission, where the sniffer was shut down over night and when a non-compliant ship has been observed that was already penalized and the airborne results may be used for an administrative penalty, in this case a calibration needs to be done after the last flight to confirm the validity of the used calibration factors.
2. Equipment[1]:
    a. Reference gas SO_2: 300-400ppb (1)
    b. Reference gas CO_2: 350-420 ppm (1)
    c. Reference gas CO_2: 450-470 ppm (2)
    d. Cart with gas cylinders equipped with regulators flowmeters and rotameter
    e. Flexible Teflon tube (3m) with Swagelok 3/8" connection (NY front ferrule) and 1/4" connection (SS)
    f. Ground Power Unit (GPU)
    g. SQMS-Follow-up.xlsx file, available on Seafile, with the active cylinders in use for calibration (see Figure 12)
3. **Duration**: 20-30 min (including warming up time: 150 min)
4. Power on Sniffer
    a. **POWER on sniffer battery with GPU** (minimum 120min before calibration)[2]
        - Connect power extension cord (if operated in Ostend, place cable protector)
        - Power on GPU and connect GPU to external sniffer battery (side connector on GPU)
        - Check on power meter if battery is fully charged (<5A) if not wait 30 min
        - OR
        - Power on GPU, plug in GPU to external AC power bus (see Figure 13)
        - In cockpit Switch on "External power supply"
        - Switch on "utility"
        - Switch on "survey power"
        - Check sniffer circuit breaker in cockpit (must be pressed down)
        - Wait 30 min
    b. Power on Sniffer
        - Master switch on sniffer box needs to be put in upward position
        - Switch on sniffer switch in cabin (at intercom jacks)

[1] No software calibration procedure is available for NO at the moment

[2] In case of cold weather <10°C the warming up time must be increased to 120 min or until the chamber temperature must is >43°C, this can checked while connecting the thermo panel (cfr 4.2 T)

- Check circuit breaker on GPU and emergency sniffer battery (must be pressed in)
- Put chart with cylinders next to aircraft (ca 3 m)
- Connect flexible hose to pitot tube via Swagelok 3/8 with inner Nylon ferrule (tighten finger tight and use 3/4 wrench to tighten 1 quarter)

5. Wait 60 min

6. Connect Laptop to MUMM_LOG_PC

a. Connect Thunderbolt cable to MUMM-LOG-PC

b. On personal Laptop open SQMS-Follow-up.xlsx on Sniffer data>>Calibration

7. CO2 software calibration

a. Enter date in first column, use Ctrl+; as shortcut

b. Check if the ref concentration matches the CO2 reference gas

c. Open IGPS (on MUMM_LOG_PC using TeamViewer)

d. Go to SNF in IGPS Software

e. Open first calibration for CO2, if none present create new one (Figure 14)

- Select “Main component”: CO2 (other components should be none)
- Check concentration and edit if necessary (300-450 ppm)
- Set “Time”: 60 Sec

f. Open gas cylinder valve

g. Connect flexible hose to required CO2 reference gas cylinder via Swagelok 1/4” (tighten finger tight and turn 1 quarter with a 7/16 wrench)

- Check pressure of the gas bottle on first manometer (min 5 bar)
- Check pressure of the output on second manometer (must be 2 bar)
- Check if over flow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
- Check reading of CO2 on IGPS software (check also if SO2 is zero)
- Optional Flush the regulator 5 times [3]
  i. close gas bottle,

h. when pressure is almost zero, close (volume) valve

i. Open gas bottle,
ii. Open (volume) valve

- Check reading on IGPS, wait (60 sec) until stable

i. On IGPS software start calibration (green light appears)

j. After calibration (60 seconds) a comment will be shown in comment log

k. go to Settings>>Utilities and check “k” en “o” Licor 7200 - CO2 (see Figure 15)

l. Disconnect flexible hose from the cylinder via Swagelok 1/4” (7/16 wrench)

m. Write down cylinder pressure and close cylinder valve

n. In SQMS-Follow-up.xlsx fill in:

- “Pressure” in active CO2-sheet
- “k” in active CO2-sheet
- “SW Offset (o)” in active CO2-sheet

8. SO2 software calibration

a. Open the SQMS-Follow-up.xlsx file go to SO2 (#) sheet and enter date (use Ctrl+;)

b. Check if the ref concentration matches the SO2 reference gas

[3] The need for flushing has to be evaluated (regularly) during operations, this can be done by comparing the CO2 gas measurement before and after flushing, if the readings are similar, flushing can be skipped for software calibrations (always do flushing for HW calibrations).

c. Open IGPS (on MUMM_LOG_PC using TeamViewer)
d. Go to SNF in IGPS software
e. Open calibration for SO2, if none present create new one (see Figure 14)
   - Select "Main component": SO2 (other components should be "none")
   - Check concentration and edit if necessary (300-400 ppb)
   - Set "Time": 120 Sec
f. Open gas cylinder valve
g. Connect flexible tube with the SO2 reference gas cylinder via Swagelok 1/4" (tighten finger tight and turn 1 quarter with a 7/16 wrench)
   - Check pressure of the gas bottle on first manometer (min 5 bar)
   - Check pressure of the output on second manometer (must be 1.5 bar)
   - Check if overflow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
   - Check reading of SO2 on IGPS software
   - Optional: Flush the regulator 5 times[4]:
     i. close gas bottle,
     ii. when pressure is almost zero, close (volume) valve,
     iii. Open gas bottle,
     iv. Open (volume) valve
        - Check reading on IGPS, wait (60 sec) until stable (write down CO2 SW zero)
h. Select "Start calibration"
   - green light appears
   - message appears: merge with old calibration: click "yes"
i. After calibration (120 seconds) a comment will be shown in comment log
j. go to Settings>>Utilities and check "k" and "o" for SO2 stream (See Figure 15)
k. Disconnect flexible hose from the cylinder via Swagelok 1/4" (7/16 wrench)
l. Write down cylinder pressure and close cylinder valve
m. In SQMS-Follow-up.xlsx fill in:
   - "Pressure" in SO2-sheet
   - "k" in SO2-sheet in "SW k-factor" column
   - "o" in SO2-sheet in "SW Offset (o)" column
n. Disconnect GPU
o. Check if external sniffer battery takes-over power supply without interruption
p. In case interruption is more than 20 min, use AC battery to power the sniffer

9. Plume simulation mixture
   a. Make sure the background values are stable for 1 min
   b. Keep the opening of the tubing upwind, avoid breathing out close to the tubing end
   c. Place the plume simulation mixture cylinder with the opening downwind
   d. Open the cylinder valve, check the pressure
   e. Release a few sudden bursts of gas to purge the regulator
   f. Hold the opening of the tubing a few cm in front of the regulator
   g. Open the toggle valve for <1 sec
   h. Check if the values for SO2 and CO2 are within limits

[4] The need for flushing has to be evaluated (regularly, eg. every 50 bar) during operations, this can be done by comparing the SO2 gas measurement before and after flushing, if the readings are similar, flushing can be skipped for software calibrations (always do flushing for HW calibrations).

- CO_2 should be below 2000 ppm
- SO_2 should be below 2000 ppb
- Clear peaks no background

i. Conduct a FSC measurement and link the measurement to the emulated AIS detection in the equator

j. Wait 1 min

k. Repeat steps f-j two more times

l. Write down the highest and the lowest of the two measurements in xls file sheet CO2+SO2

m. The updated FSC span and offset are displayed in column K and J

n. Check if the measured FSC falls within the acceptable limits

- On graph the average FSC (Red line) must fall withing the dotted lines
- The FSC values that fall outside the limit will be highlighted in red

o. In case the average values falls outside the limits, the new span and offset must be entered in the ini file for all IGPS stations used for the measurements (1 operator laptop + MUMM-LOG-PC)

- Close IGPS present
- On MUMM-LOG-PC only: close watchdog and close IGPS present again
- Open C:\IGPS\AISPresent.ini
- Scroll down to:

```
….
FSC_Span = 1.2571
FSC_Offset = 0.0007
….
```

- Replace the old span and offset values with the new offset and span values
- Save the AISPresent.ini file
- On MUMM-LOG-PC reopen watchdog from C:\IGPS\WatchdogIGPSpresent
- Set the value in column K to "Y"
- Open C:\IGPS\Thresholds, BIAS and SFOC-2022.xls go to sheet "FSC→Bias correctie"
- Enter flight number and date
- Copy the new FSC span and offset values

p. In case the average FSC value does not fall not outside the limits

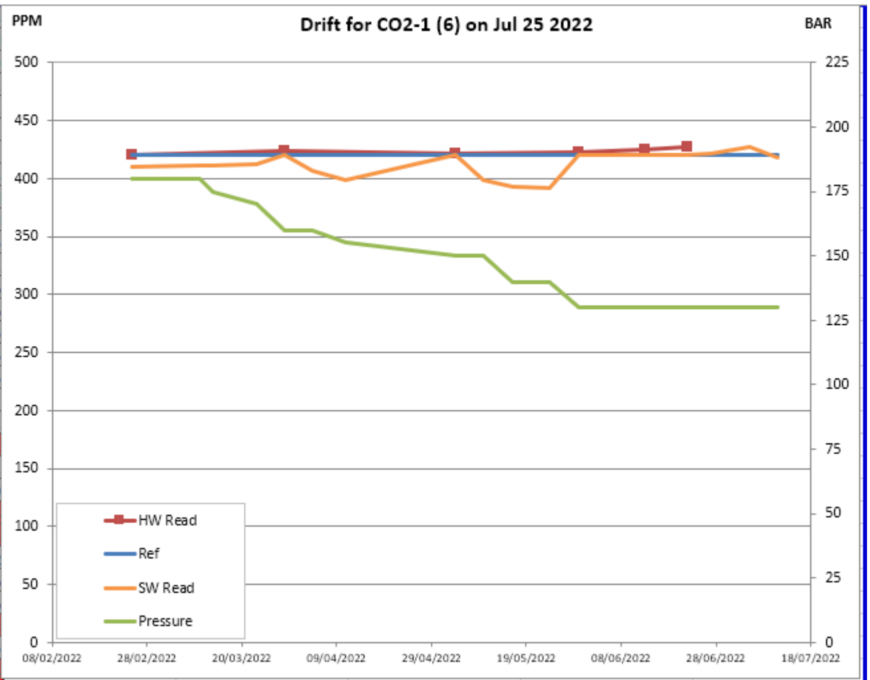
- Set the value in column K to "N"

10. Before take-off

a. Disconnect tubing and remove chart

b. Keep GPU power up to 5 min before starting of the engines

Manufacturer	Airplus
Gas botle ref	GQ84FNN
MUMM reference	CO2-1 (6)
Purchase date	27/08/2021
Delivery date	01/12/2021
Start date	21/02/2022
End Date	
Duration	154 Days
Requested concentration	420.0 PPM
Commercial concentration	420.0 PPM
Warranty	10/09/2026
Error absolute	2.1
Error percentage	0.500%
Actual error	0%
Traces of SO2	0.1 PPB
Traces of NO	0.3 PPB
Traces NO2	0.0 PPB
Nr of calibrations for 50 bar	17
Pressure for GAS calibration	3.1
Date of last HW calibration	22/06/2022
Date of last gas calibration	11/10/2021
Date of last HW Check	27/01/2020
SW calibration needed	Yes
HW calibration needed	Yes
Referene Gas Drift	Data missing
Software drift	2.59%
Sensor drift	0.62%
Gas calibration warning	Yes
Gas +1 calibration warning	No
HW check needed	Yes



Date of calibration	REF	Software		Hardware		Pressure
		SW k-factor	SW Offset (o)	HW Read	HW Zero	
30/05/2022	420.0 PPM	1.000	0.000	422.0 PPM	-2.0 PPM	130 Bar
13/06/2022	420.0 PPM	1.000	0.000	421.0 PPM		130 Bar
22/06/2022	420.0 PPM	1.000	0.000	422.0 PPM	0.0 PPM	130 Bar
27/06/2022	420.0 PPM	0.995	0.530			130 Bar
05/07/2022	420.0 PPM	0.991	-3.621			130 Bar
11/07/2022	420.0 PPM	0.997	2.750			130 Bar

Figure 68 Print screen from the SQMS-Follow-up.xlsx file

Figure 69 During calibration the aircraft is powered with the GPU (note: charging should occur through the emergency power battery and not via the external power port)

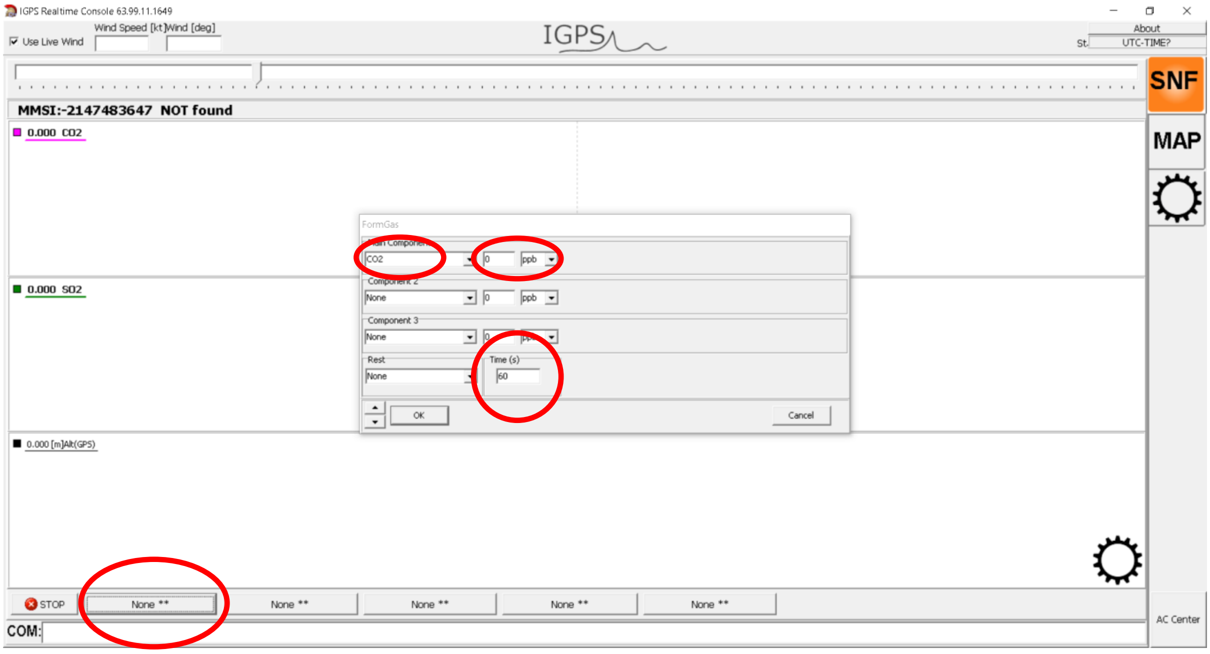


Figure 70 To start new calibration setting, select "None" in "SNF" view, a pop-up window will open, select the component (SO2 or CO2) enter concentration (in ppb or ppm) and select time (120 sec for SO2; 60 sec for CO2)**

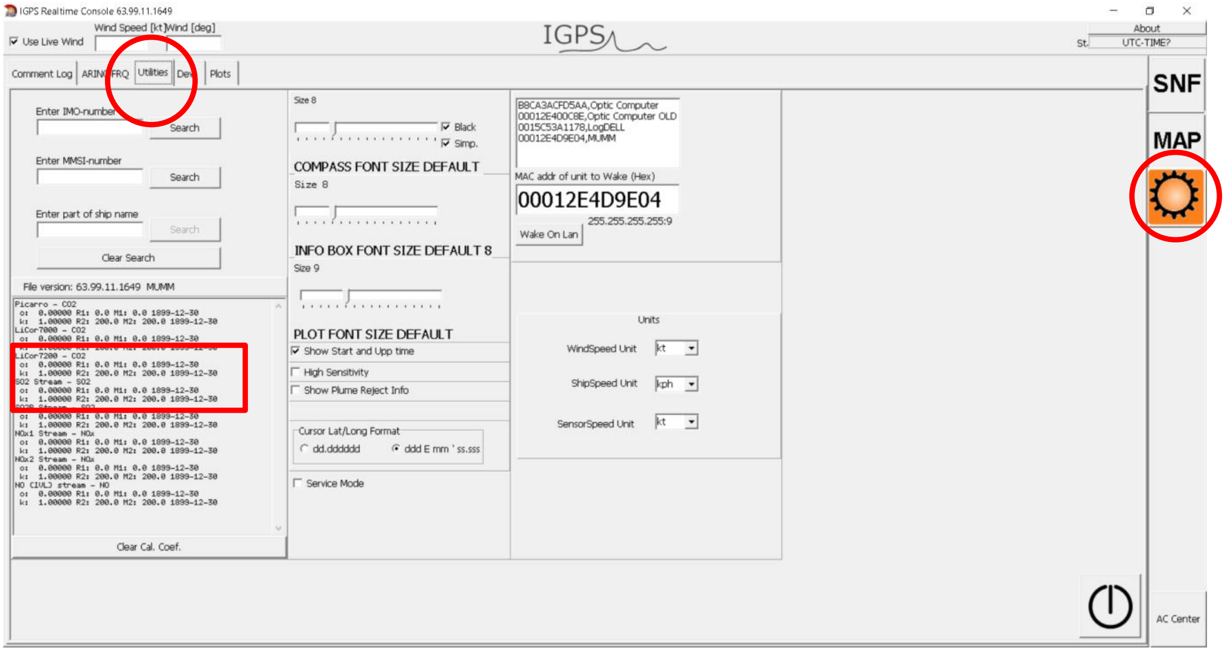
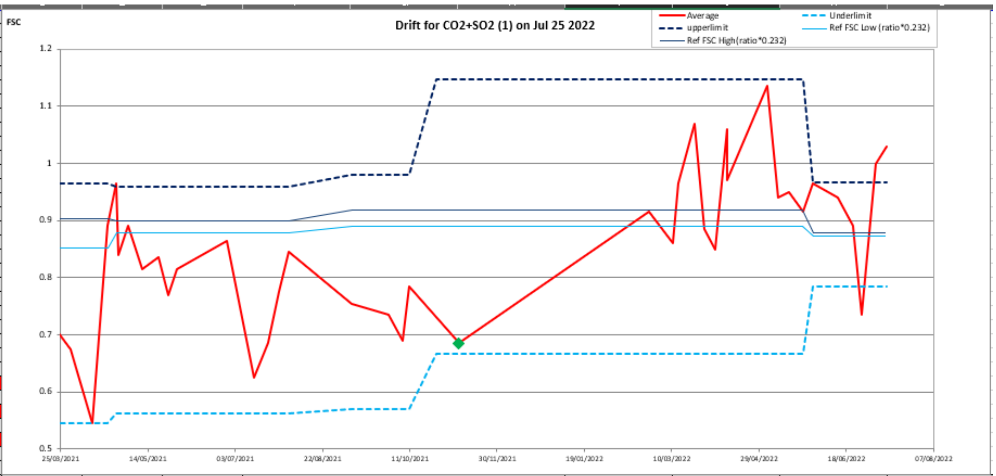


Figure 71 After (complete) calibration the new calibration factors (k and o) are visible under settings view (cog wheel) under "Utilities" tab

Manufacturer	Airliquide
Gas botle ref	L0P8RCE
MUMM reference	CO2+SO2 (1)
Volume (l)	10 L
Purchase date	10/05/2019
Delivery date	03/07/2019
Start date	23/10/2019
End Date	
Duration	1006 Days
Requested concentration	1.16 %FSC
Commercial concentratio	0.00 %FSC
Warranty*	18/06/2020
Error absolute	#DIV/0!
error percentage	#DIV/0!
Actual error	#DIV/0!
Traces of NO	60.0 PPB
Traces of Nox	2,750.0 PPB
SO2 (pppm)	1,148.0 PPB
CO2	301.0 PPM
Bias relatief	1.16
Bias absoluut	0.0057
Median FSC AC	0.05
Median FSC PSC	0.0600
Span FSC	1.22
Offset FSC	0.0044
Date of last Gas Callibratio	25/05/2022
Plume Bias Check neede	Yes
Re-calibration needed	No
FSC Span adjustment ne	Yes
Referene Gas Drift	3.19%
Gas calibration warning	Yes
Gas +1 calibration warning	No
FSC NO error	0.00026



Date of software calibration	Ref FSC Low (ratio*0.232)	Ref FSC High(ratio*0.23	Underlimit	upperlimit	FSC min FSC	FSC max FSC	FSC Average	Span (FSC)	Offset (FSC)	Replacement Span and offset	Pressure
16/05/2022	*0.89 %FSC*	*0.92 %FSC*	0.67 %FSC	1.15 %FSC	0.90 %FSC	1.00 %FSC	0.95 %FSC	**1.0953**	**0.0078**	**N**	65 Bar
24/05/2022	*0.89 %FSC*	*0.92 %FSC*	0.67 %FSC	1.15 %FSC	0.89 %FSC	0.94 %FSC	0.92 %FSC	**1.1401**	**0.0056**	**N**	65 Bar
30/05/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.89 %FSC	1.04 %FSC	0.97 %FSC	**1.0411**	**0.0106**	**Y**	65 Bar
13/06/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.91 %FSC	0.97 %FSC	0.94 %FSC	**0.9644**	**0.0152**	**N**	60 Bar
22/06/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.86 %FSC	0.92 %FSC	0.89 %FSC	**1.0225**	**0.0117**	**N**	55 Bar
27/06/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.70 %FSC	0.77 %FSC	0.74 %FSC	**1.2571**	**0.0007**	**Y**	50 Bar
05/07/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.97 %FSC	1.03 %FSC	1.00 %FSC	**1.0917**	**0.0080**	**N**	
11/07/2022	*0.87 %FSC*	*0.88 %FSC*	0.79 %FSC	0.97 %FSC	0.99 %FSC	1.07 %FSC	1.03 %FSC	**1.0568**	**0.0098**	**N**	

Figure 72 SQMS-follow up file with CO2+SO2 sheet

CHAPTER 4. HARDWARE CALIBRATIONS

Note: the sniffer has to be warmed up 120 min. before an SO2 hardware calibration!

SOP 2.3. Hardware calibration general preparation

1. **When:** Hardware calibration of SO2 and CO2 sensors is required in following cases:
    a. minimum every month, **OR**
    b. SW calibration factors are outside boundaries (see 4.1 and 4.2), **OR**
    c. After lab-calibration of reference gasses (see Chapter 4.1)

Note: The need for a HW calibration will be automatically displayed in the header of the different cylinder sheets in the SQMS-Follow-up.xlsx file (see Figure 12).

2. General Equipment:
    a. Chart with gas bottles equipped with regulators flowmeters and rotameters
    b. Flexible hose of 3m with Swagelok 3/8" (with inner NY ferule) to Swagelok 1/4"
    c. Ground Power Unit (GPU)

4.1. Licor 7200RS

Note: the hardware calibration for the LOCOR 7200RS sensor is not time consuming and can be done without removing the sniffer. Therefore, it can be advised to perform a hardware CO2 (span) calibration before every software CO2 calibration.

SOP 2.4. CO2 hardware calibration

1. Boundaries
    a. Offset: -3-10 ppm
    b. Slope K: 0.6-1.15
2. Specific equipment:
    a. Low Span gas CO_2 (Span 1): 350-400 ppm in synthetic air
    b. High Span Gas CO_2 (Span2): 400-450 ppm in synthetic air
    c. Zero gas or SO_2 reference gas, all SO_2 concentrations (in synthetic air) can be used

Note: difference between 2 span gasses should not be smaller than 30 ppm or bigger than 100 ppm, ideally this should be round 50 ppm.

3. **Duration**: 10 min (including warm up time: 30 min)
4. Preparation
    a. Connect power extension cord
    b. Plug in GPU to external AC power bus
    c. Power on GPU
    d. In cockpit Switch on "External power supply"
    e. Switch on "utility"
    f. Switch on "survey power"
    g. Check sniffer circuit breaker in cockpit (must be pressed down)
    h. Master switch on sniffer box needs to be put in upward position

- **i.** Switch on sniffer with remote switch in cabin (at intercom jacks)
- **j.** Check circuit breaker on emergency sniffer battery (must be pressed in)
- **k.** Put chart with cylinders next to aircraft (ca 3 m)
- **l.** Connect flexible hose to sampling tube via Swagelok 3/8 with inner Nylon ferrule (tighten finger tight and use 3/4 wrench to tighten 1 quarter)

5. Wait 30 min

6. Connect Laptop to MUMM_LOG_PC

- **a.** Connect laptop with Thunderbolt cable
- **b.** Connect to MUMM_LOG_PC using TeamViewer (V12) use 192.168.1.9 (make sure TeamViewer accepts LAN connections) and pwd: “mumm”
- **c.** Go to LICOR software GHG V8.0 (on MUMM_LOG_PC)
- **d.** Connect to Licor sensor via Ethernet (IP: 192.168.1.95; Port 7200; Update frq: 1 Hz)
- **e.** Open SQMS-Follow-up.xlsx on Sniffer data>>Calibration

7. CO2 zero calibration

- **a.** On Zero gas or SO2 span gas
- **b.** Open gas cylinder valve
- **c.** Connect flexible hose to the zero gas cylinder via Swagelok 1/4” (tighten finger tight and turn 1 quarter with a 7/16 wrench)
  - Check pressure of the gas bottle on first manometer (min 5 bar)
  - Check pressure of the output on second manometer (must be 1.5 bar)
  - Check if over flow is 0.8, if necessary adjust volume (ca 9-11 l/min)
  - Check reading of CO2 on GHG software
  - Flush the regulator 5 times:
    - i. close gas bottle,
    - ii. when pressure is almost zero, close (volume) valve,
    - iii. Open gas bottle,
    - iv. Open (volume) valve
  - Check reading on GHG, wait (60 sec) until stable (HW zero)
- **d.** On GHG software: Go to LI-7200>>Calibration>>Zero
- **e.** Select “zero CO2”
- **f.** Message appears, “This will do a CO2 zero, Do you want to continue?” click “yes”
- **g.** Check if the CO2 read is 0, if not repeat steps d to f
- **h.** Disconnect flexible hose from the cylinder via Swagelok 1/4” (7/16 wrench)
- **i.** Write down cylinder pressure and close cylinder valve
- **j.** In SQMS-Follow-up.xlsx fill in “HW zero” in both CO2-1 and CO2-2 sheets

8. CO2 span calibration (1)

- **a.** Two span gasses are needed for the HW calibration (with difference of 50 ppm). It is advised to regularly switch the sequence of the SPAN gasses between HW calibration, therefore use the span gas for which no SW calibration is needed first (span gas with indication “No” behind “SW calibration needed” in SQMS-Follow-up.xlsx s file header, see Figure 12)
- **b.** Open gas cylinder valve
- **c.** Connect flexible hose to the span 1 gas cylinder via Swagelok 1/4” (tighten finger tight and turn 1 quarter with a 7/16 wrench)
  - Check pressure of the gas bottle on first manometer (min 5 bar)
  - Check pressure of the output on second manometer (must be 2 bar)

- Check if over flow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
- Check reading of CO2 on GHG software
- Flush the regulator 5 times:
  i. close gas bottle,
  ii. when pressure is almost zero, close (volume) valve,
  iii. Open gas bottle,
  iv. Open (volume) valve
- Check reading on GHG, wait (60 sec) until stable (HW Read)

d. On GHG software: Go to LI-7200>>Calibration>>Span (2)
e. Check "Span gas concentration" with concentration on cylinder and SQMS-Follow-up.xlsx
f. Select "Span (2) CO2"(two flags must be green)
g. A message appears: "confirm span calibration?", Click "Yes"
h. Check if the CO2 read is span gas concentration, if not repeat steps d to g
i. Disconnect flexible hose from the cylinder via Swagelok 1/4" (7/16 wrench)
j. Write down cylinder pressure and close cylinder valve
k. In SQMS-Follow-up.xlsx fill in:

- "Pressure" in CO2-1 (2) sheet
- "HW read" in CO2-1 (2) sheet (value before calibration)

9. CO2 span2 calibration

a. Two span gasses are needed for the HW calibration (with difference of 50 ppm). It is advised to regularly switch the sequence of the SPAN gasses between HW calibration, therefore use the span gas for which a SW calibration is needed at last (span gas with indication "Yes" behind "SW calibration needed" in SQMS-Follow-up.xlsx s file header, see Figure 12)
b. Open gas bottle
c. Connect flexible hose to the span gas cylinder (selected for SW calibration) via Swagelok 1/4" (tighten finger tight and turn 1 quarter with a 7/16 wrench)

- Check pressure of the gas bottle on first manometer (min 5 bar)
- Check pressure of the output on second manometer (must be 2 bar)
- Check if over flow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
- Check reading of CO2 on GHG software
- Flush the regulator 5 times
  i. close gas bottle,
  ii. when pressure is almost zero, close (volume) valve,
  iii. Open gas bottle,
  iv. Open volume valve
- Check reading on GHG, wait (60 sec) until stable (HW Read)

d. On GHG software: Go to LI-200>>Calibration>>Span (2)
e. Check "Span (2) gas concentration"
f. Select "Span (2) CO2"(two flags must be green)
g. A message appears: "confirm span calibration?", Click "Yes"
h. Check if the CO2 read is span gas concentration, if not repeat steps d to g
i. Disconnect flexible hose from the cylinder via Swagelok 1/4" (7/16 wrench)
j. Write down cylinder pressure and close cylinder valve
k. In SQMS-Follow-up.xlsx fill in:

- "Pressure" in CO2-2 sheet

- "HW read" in CO2-2 sheet (value before calibration)

10. Reset the IGPS calibration factors (see 7.1 Reset software calibration factors) [5]

Note: H2O should not be calibrated as this information is not used in the sniffer sensor setup

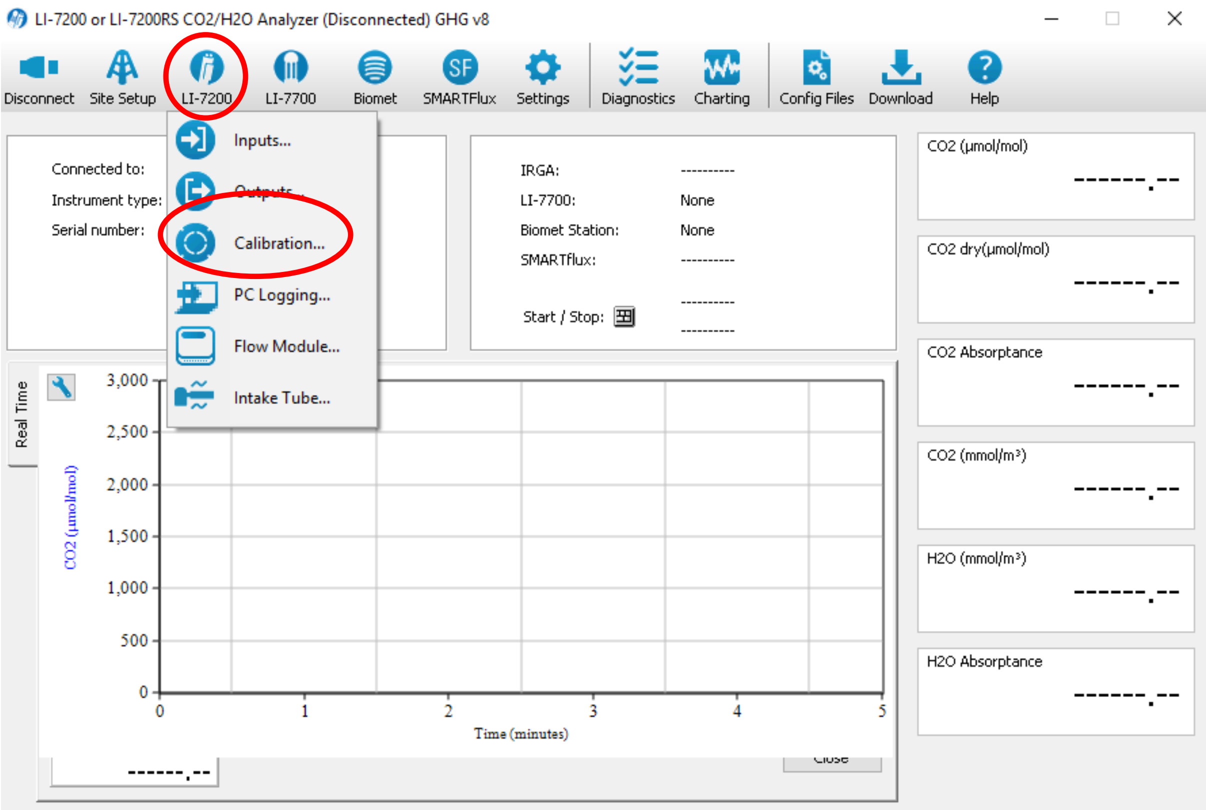


Figure 73 Main view of the Licor GHG v8 software, to start calibration go to LI-7200>>Calibration

[5] Note that after reset of the calibration factors either a SO2 hardware or SO2 software calibration must be performed

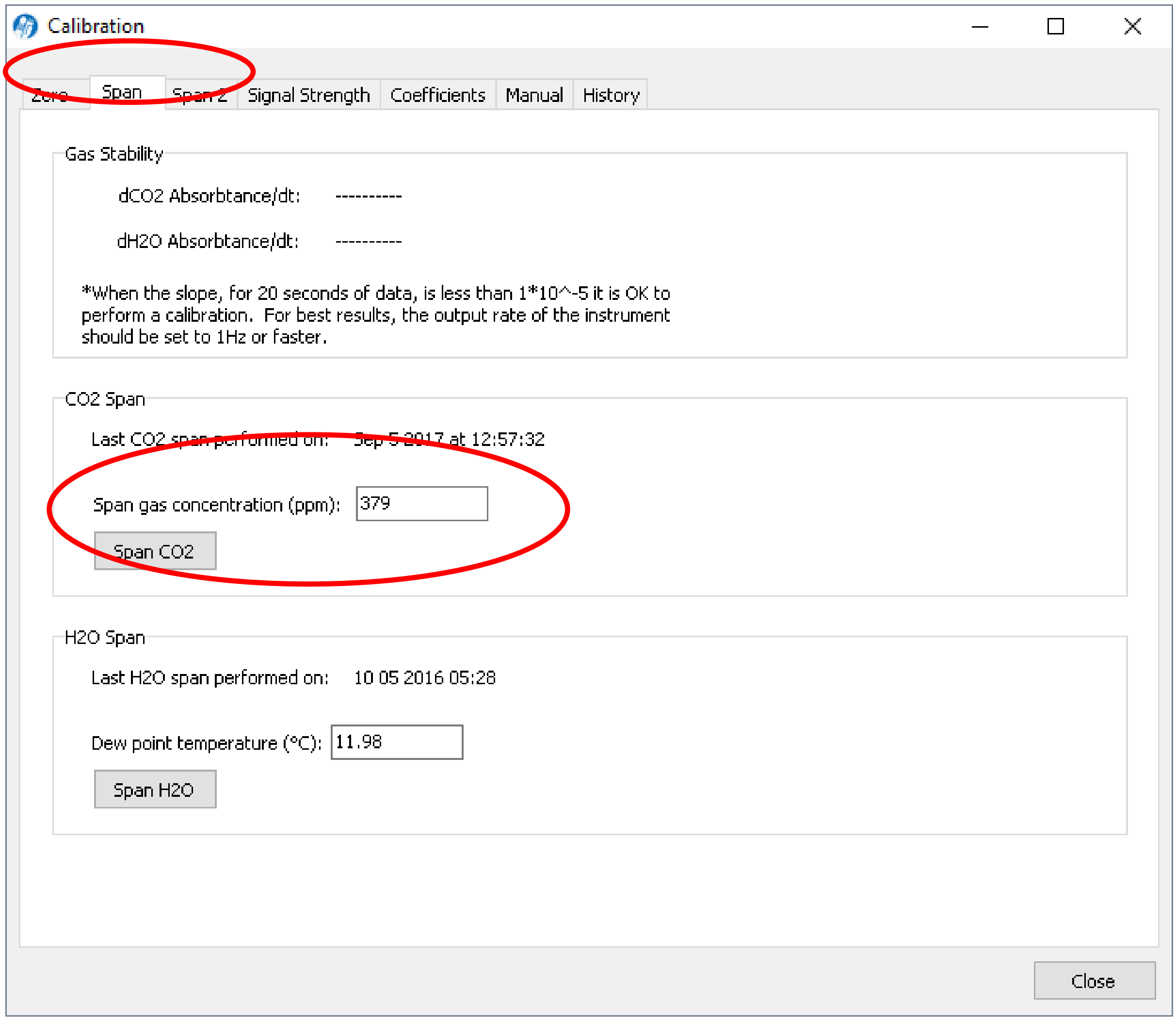


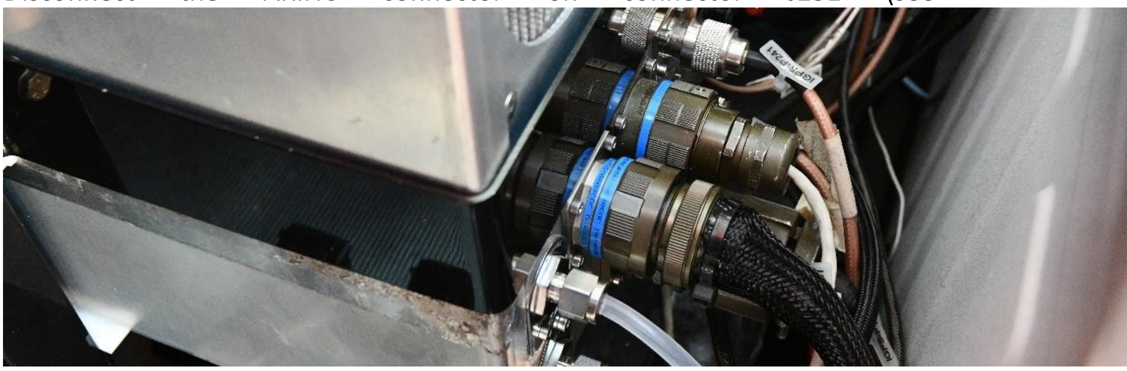
Figure 74 Use the Zero, Span or Span 2 tabs, enter the span gas concentration and press span CO2

4.2. Thermo 43i TLE

Note: the preparatory work under option 2 is more time consuming as in this case the sniffer has to be demounted and opened, therefore option 2 should only be used in case the sniffer has to be opened for other purposes.

SOP 2.5. SO2 hardware calibration

1. Boundaries
   a. Offset: -5-20 ppb
   b. Slope K: 0.6-0.15
2. Specific equipment
   a. Thermo box (front panel mounted in ruggedized case)
   b. Zero (background) gas: zero gas or both CO_2 reference gas cylinders can be used (use the one with highest pressure) also a zero filter can be used.
   c. Span Gas SO_2: 300-450 ppb (in synthetic air)
3. Specific equipment for Option 2 (demounting of the sniffer)
   a. Tools: wrenches 3/8, 7/16, electrical screwdriver, Torx T10,
   b. Flatbed screwdriver
   c. Optional: ribbon cable
   d. Flexible tubing with 1/4 Swagelok connectors
   e. white jumper for power supply cable to the
4. **Duration preparatory work**: option 1: 5 min, option 2: 60 min (warming up time: up to 180 min)
5. Duration HW calibration: 10 min
6. By who: Can only be executed by qualified representative or members from FluxSense/MUMM, 2 persons are needed for the preparatory work under option 2 for the Thermo calibration
7. Preparatory work
   a. Preparatory work option 1
      - Disconnect the ARINC connector on connector J251 (see



      - Figure 75)
      - Put Thermo box on top of the sniffer and take out the cable with the MIL connector
      - Connect the cable with connector J251 (see Figure 76)
      - Connect flexible hose to sampling tube via Swagelok 3/8 with inner Nylon ferrule (tighten finger tight and use 3/4 wrench to tighten 1 quarter)

- Connect power extension cord (place cable protector if needed)
- Plug in GPU to external AC power bus and power on GPU
- Switch on "External power supply"
- Switch on "utility"
- Switch on "survey power"
- Check circuit breaker of sniffer in cockpit
- Switch on sniffer in cabin
- Check circuit breaker on emergency sniffer battery
- Switch on main power switch on sniffer (switch has to be faced upward)
- Check if the Thermo panel lights up and if data is collected

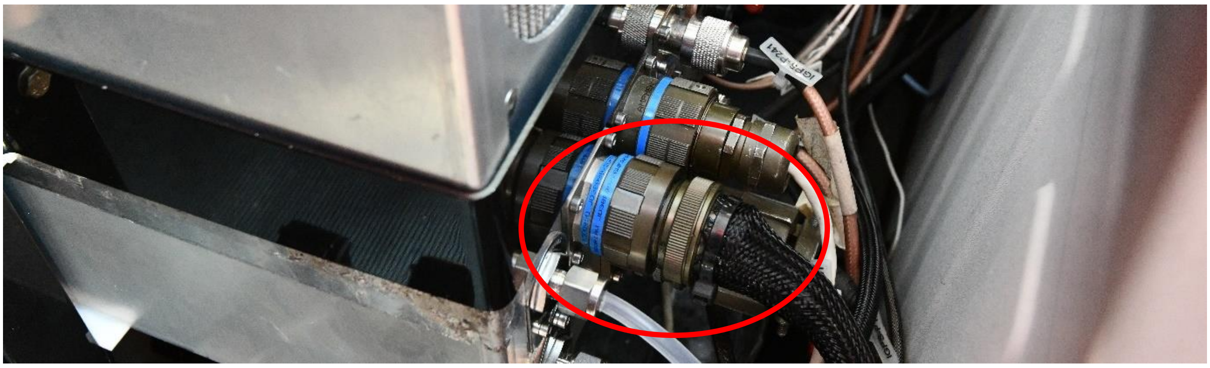


Figure 75 Location of the J251 ARINC connector

Figure 76 Placement of the Thermo panel box on top of the sniffer and connection to the J251 connector

b. Preparatory work option 2 (requires opening of sniffer)

> **Danger for equipment damage! Some internal components can be damaged by small amounts of static electricity. A properly ground antistatic wrist strap must be worn while handling any internal component while the sniffer is powered on.**

- Demount the sniffer from the aircraft (see 6.1), move the Sniffer to the workshop
- Open the top compartment (see 6.1)
- In case the Arinc connector can be used the thermo box can be connected using the J251 cable **OR**
- In case the Arinc connector cannot be used: take the thermo panel out of the ruggedized case and position it close to the motherboard of the Thermo, connect the ribbon cable from the front panel straight to J1 on to the motherboard (see Figure 77)
- Demount the sniffer pitot tube from the aircraft belly and position it next to Sniffer, connect the pitot tube to the air inlet using the flexible tube with 1/4" Swagelok connections on both ends used for troubleshooting (tighten finger tight and use 7/16 wrench to tighten 1 quarter)
- Put the SO2 reference gas cylinder next to the sniffer
- Connect flexible hose to the regulator of the SO2 cylinder with 1/4" Swagelok connector (tighten finger tight and use 7/16 wrench to tighten 1 quarter)
- Connect flexible hose to pitot tube via Swagelok 3/8 with inner Nylon ferrule (tighten finger tight and use 3/4 wrench to tighten 1 quarter)
- Connect 115V power socket (J233) with Thunderbolt docking station power adapter

- Connect HDMI cable with VGA converter and connect to monitor
- Connect Ethernet cable to Thunderbolt dock (J221)
- Connect power cable to GPU (62GB-56TG14-02PN)
- Connect the other outlet of the power cable to the sniffer (J211)
- Install white jumper on the power cable
- Power on GPU
- Switch on main power switch on sniffer (switch must be faced upward)

8. Wait 60-120 min (check chamber temperature (ALARM), must be between 43 and 47°C)

9. Connect Laptop to MUMM_LOG_PC

- **a.** Connect laptop with Thunderbolt cable
- **b.** Switch off all other non-used network adapters (WIFI and Ethernet)
- **c.** Connect to MUMM LOG-PC using TeamViewer us 192.168.1.9 (make sure TeamViewer accepts LAN connections)
- **d.** On Laptop open SQMS-Follow-up.xlsx on sniffer data>>Calibration

Note: To use the PC next to the Sniffer sensor, an Ethernet cable can be used instead of the Thunderbolt Dock, in this case it is required to adjust the IP address of the network adapter, a list with the available IP addresses is provided in the IGPS folder and in 1.7 External signal wiring

10. SO2 background calibration

- **a.** Connect flexible hose to a Zero gas or CO2 reference gas via Swagelok 1/4" (tighten finger tight and turn 1 quarter with a 7/16 wrench)
- **b.** Open gas bottle
    - Check pressure of the gas bottle on first manometer (write down)
    - Check pressure of the output on second manometer (must be 2 bar)
    - Check if over flow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)
    - Check reading of SO2 on front panel (must be close to 0)
    - Flush the regulator 5 times:
        - i. close gas bottle,
        - ii. when pressure is almost zero, close (volume) valve,
        - iii. Open gas bottle,
        - iv. Open (volume) valve
    - Check reading on front panel, wait (60 sec) until stable
- **c.** On front panel, open menu
- **d.** Go to Calibration by using click enter
- **e.** Go to SO2 Background (see Figure 79)
- **f.** Select enter
- **g.** Wait 10 seconds
- **h.** Select enter again
- **i.** Continue until SO2 reading is close to 0

11. SO2 span calibration

- **a.** Connect flexible hose to SO2 reference gas via Swagelok 1/4" (tighten finger tight and turn 1 quarter with a 7/16 wrench)
- **b.** Open gas bottle
    - Check pressure of the gas bottle on first manometer (min 10 bar)
    - Check pressure of the output on second manometer (must be 1.5 bar)
    - Check if overflow is 0.8 l/min, if necessary adjust volume (ca 9-11 l/min)

- Check reading of SO2 on front panel
- Flush the regulator 5 times
  i. close gas bottle,
  ii. when pressure is almost zero, close (volume) valve,
  iii. Open gas bottle,
  iv. Open (volume) valve
- Check reading on front panel, wait (120 sec) until stable (HW Read)

c. On front panel, open menu

d. Go to Calibration by using ⬇ ⬆ click enter ↵

e. Go to SO2 coefficient (see Figure 79)

f. Enter the concentration (using ⬇ ⬆)

g. Select enter ↵

h. Wait 10 seconds

i. Select enter again

j. Go back to Main menu and Open calibration factors submenu

k. Continue until SO2 value is close to the reference gas value

l. Open SQMS-Follow-up.xlsx>> SO2 (#) sheet

m. Enter the “SO2 COEF” value in “HW k-factor (COEF)” column

n. Enter “SO2 BKG” value in “HW Offset (BKG)” column

o. Enter cylinder pressure at end of measurement in “Pressure” column

12. Reinstallation sniffer in case of option 2

a. Power down Sniffer (shut down from the MUMM_LOG_PC)

b. Remove the Thermo front panel and ribbon cable

c. Reinstall the cover, make sure to reconnect the cable for the fan and make sure it does not touch the fans

d. Reinstall the sniffer in the aircraft and reconnect all cabling

e. Reinstall the pitot tube at the AC belly

f. Perform SO2 software calibration (see chapter 2) or clear the IGPS calibration factors (see 7.1 Reset software calibration factors)

Note: The replacement of the filters and other sensor maintenance can be combined during the SO2 hardware calibrations to minimise the dismantling of the sniffer (see Chapter 6)

Figure 77 Connection of the Thermo front panel to the internal Thermo motherboard (J1) with ribbon cable

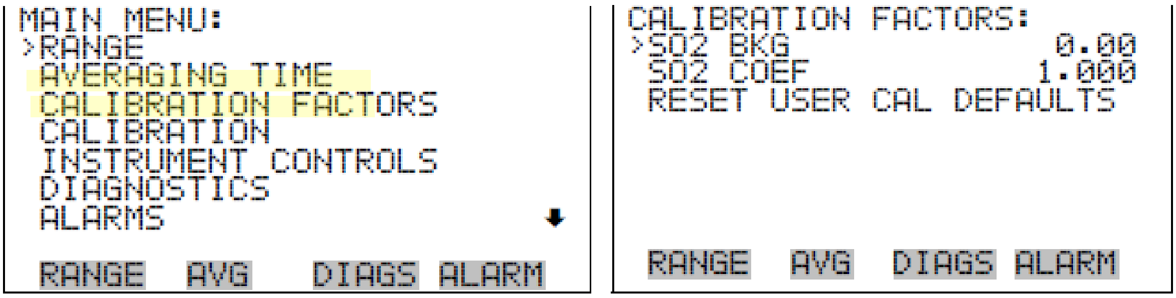


Figure 78 Main menu and calibration factor menu

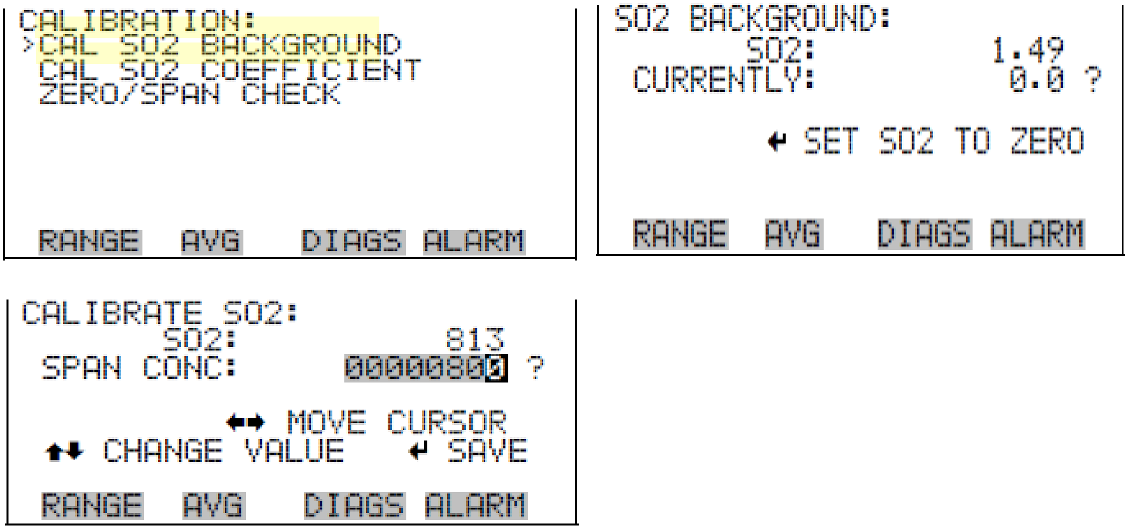


Figure 79 Calibration menu, SO2 background calibration and SO2 Coefficient calibration

4.3. Ecotech Serinus 40

To perform a hardware calibration of the Ecotech Serinus 40 sensor. The most convenient way is to use an android smartphone with Bluetooth connection, this will copy the display of the sensor and the command buttons. The application used for the connection is Serinus and is currently only available on android. A dedicated android smartphone is available with the Serinus application.

SOP 2.6. NOx hardware calibration

1. Specific equipment
    - a. Smartphone with Serinus application)
    - b. Zero (background) gas: zero gas or both CO_2 reference gas cylinders can be used (use the one with highest pressure) also a zero filter can be used.
    - c. Span Gas NO: 300 ppb (in N2)
2. Duration warming up: up to 180 min
3. Duration HW calibration: 10 min
4. By who: SURV crew
5. Hardware NO zero and NO2 zero calibration
    - a. Connect smartphone:
        - On the smartphone open Serinus app,
        - Scan devices and select the NOx sensor ()

b. Set gas to measure to NOx, NO and NO2
- Go to the Quick menu>>Gas to measure>>
- Select “All” and click accept

c. Set filter to 30 seconds
- Go to main menu>>Measurement settings>>Filter
- Set to to 30 seconds
- Go back to main menu
- Wait 2 minutes

a. Enter the read of the sensor for NO in the xls file (Zero read).
b. Go to the main menu>>calibration menu.
c. Select “Zero calibrate NO” and select “enter”.
d. In case an error message appears, click “ok”.
e. Select “Zero NO2” and select “enter”.
f. In case an error message appears, click “ok”.
g. Zero values should be within range of +/- 2ppb , if not repeat steps c-f.
h. Remove the flexible tubing and close toggle valve.

1. Hardware NO and NOx calibration

a. Open NO gas cylinder and connect flexible hose (wait 120 sec)
b. Enter the read of the sensor for NO in the xls file (HW read).
c. Go to the main menu>>calibration menu.
d. Select “Span Calibrate NO”, check value with last noted value on cylinder, and select “Accept”.
e. In case an error message appears, click “Yes”.
f. Select “Span Calibrate NOx” check value with the sum of the last noted value + traces of NO2,
g. Verify on IGPS if the values for NO remain slightly lower than the values for NOx for 30 seconds and are within +/- 5ppb range of span value.
h. If this is not the case reperform span calibration of NO and/or NOx until values are satisfactory.
i. Disconnect flexible hose from regulator and close toggle valve
j. Set filter back to 1 second
- Go to main menu>>Measurement settings>>Filter
- Set to 1 second

k. Set gas to measure to NOx
- Go to the Quick menu>>Gas to measure>>
- Select “NOx” and click accept

CHAPTER 5. MANAGEMENT REFERENCE GASSES

Both the sensor as the reference gasses may experience drift behaviour, to avoid sensor drift, regular software and hardware calibrations are required, these calibrations have only meaning if the concentrations in the reference gas is correct. When the gas concentration of SO2 or CO2 is not stable, this is called drift when this occurs it has significant implications on the sensor and hardware calibrations and therefore also on the emission measurements. This chapter describes the required aspects of an appropriate management of the reference gasses to ensure the proper calibrations of the sniffer sensor system and the provision of accurate measurements.

5.1. Gas mixtures

Following gas mixtures are required for the Sniffer sensor system:

- **CO2 span gasses** are used for the calibration of the IGPS software and Licor sensor. They can be purchased from Airproducts in cylinders of 10l with a DIN6 connection. The gasses should be ordered with an accuracy of at least 5% . They last 1 to 2 years and come with a warranty of 2 years. 2 concentrations are required:
  6. Low Span gas CO_2 (Span 1): 420 ppm in synthetic air
  7. High Span gas CO_2 (Span2): 470 ppm in synthetic air

Note: difference between 2 span gasses should not be smaller than 30 ppm or bigger than 100 ppm, ideally this should be round 50 ppm.

- **SO2 span gas** is used for the calibration of the IGPS software and Thermo sensor. This mixture can be purchased from Airproducts in cylinders of 10l with a DIN1 connection. Ordered gasses should have an accuracy of 5%. They last 1 year and come with a warranty of 1 years. Only 1 concentrations is required:
  8. Span gas SO2: 400 ppb (in synthetic air)
- **NO gas** is used for the calibration of the Ecothech sensor. This mixture can be purchased from Airproducts in cylinders of 10l with a DIN1 connection. Ordered gasses should have an accuracy of 5%. Only 1 concentrations is required:
  9. Span gas NO: 300 ppb (in nitrogen)
- **Zero gas/zero filter** is used for the background or the zero calibrations of the Thermo and Licor sensor, a dedicated Zero gas mixture or filter can be purchased from Airproducs. Alternatively, a SO2 gasmixture can be used for the calibration of the Licor sensor and the CO2 gasmixtures can be used for the zero calibrations of the Thermo sensor and the Ecotech sensor.
- Special **plume simulation gas mixture**, this mixture is used to provide a real life test of the sniffer sensor and allows to adjust the FSC span and FSC offset values. This mixture corresponds to an FSC of ca. 1% and consists of:
  10. Mixture of 10000 ppm CO2 and 50000 ppb SO2 in synthetic air

Note: When using respective SO2 and CO2 gas mixtures for the zero calibration of the Licor and Thermo sensors, the gas mixtures have to be analysed for their trace levels of CO2 and SO2

5.2. Installation cylinders on the gas chart

The cylinders should be installed on the gas chart when used during calibration. Preferably the following setup should be used when installing the cylinders: CO2-1, CO2-2, SO2, NO on the back and synthetic air and the plume simulation mixture in front (Figure 80). When installing the cylinders, pay attention to the position of the valve so that the regulators can be installed afterwards without further manipulation of the cylinder. Attach the cylinders to the cart using a heavy-duty strap with ratchet, make sure to avoid a loose end on the strap. After the installation of the cylinders the regulators can be mounted on the cylinders.

Figure 80 Attachment of 5 cylinders on the gas chart

5.3. Assembling regulator

The pressure regulator for the reference gas cylinders depends on the type of gas. CO2 gas mixtures are considered non corrosive and cylinders are ordered with DIN6 connection (W 21.80x1/14” right turn). SO2 and NO mixtures are considered corrosive, therefore special regulators are used, these come with DIN1 connection (left turn).

Following regulators with volumeters are used

- CO2

  11. Regulator: HBS-200-3-2-5 (Airliquide)
  12. Volumeter: DYNAVAL_N2

- SO2 and NO

  13. Regulator: HBSI_200-1-2 (Airliquide)
  14. Volumeter: MILLIMITE.S_200-0_02_AN

- Synthetic air

  15. Regulator: R303 (Air products)
  16. Volumeter: MILLIMITE.S_200-0_02_AN

- Plume simulation mixture

  17. Regulator Messer: Spectron FM51

In addition, to make sure there is sufficient overflow, regulators 1-3 are equipped with a Brooks rotameter: 2510 A 2A13 S N VT and all regulators have a Swagelok toggle valve SS-1GS4.

Note: The plume simulation mixture is not equipped with an overflow as this regulator should never be connected straight to the tubing.

SOP 2.7. To install the regulator on the cylinder

1. Place main air inlet (see nr 4 in Figure 81)
2. Tighten the main nut
   a. For CO2 cylinders turn the nut clockwise
   b. For SO2 cylinders turn the nut counter-clockwise
3. Tighten with relative force with an adjustable spanner
4.

SOP 2.8. To remove the regulator from the reference gas cylinder

1. Make sure the cylinder valve is closed and the pressure is equal to the atmospheric pressure on the regulator (1 bar), therefore the toggle valve should be open (upward position).
2. Untighten the nut at the regulator intake (see nr 4 in Figure 81)
   a. For CO2 cylinders turn the nut counter-clockwise
   b. For SO2 cylinders turn the nut clockwise
   c.

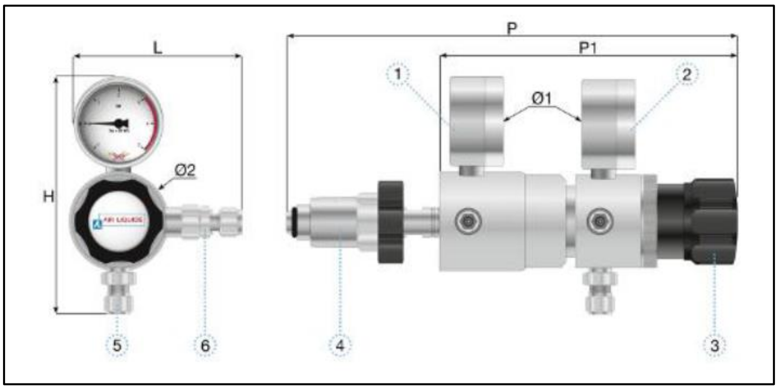


Figure 81 Regulator HBS-200-3-2-5 for Airliquide cylinders (used for CO2 mixtures)

5.4. Purchase orders / administration

Lead times may vary from a few weeks to several months, therefore it is advised to always have at least 2 cylinders of a reference gas in storage. As soon as the active gas cylinder is below 25 bar a new cylinder should be ordered. The main contractors for MUMM are Airliquide (before) and Airproducts (current), other contractors are e.g. Messer (note that changing contractor may require the purchase of a new regulator). Documentation about the orders can be found in the Calibration gasses folder (soft and hard copy).

Note: Before returning a cylinder make sure the cylinder is empty (clearly write "empty" on bottle)

5.5. Calibration of reference gasses

Reference gasses are provided with a factory accuracy of 5% and a 1-3 year warranty, nevertheless it has been observed that actual concentrations may differ up to 20% from the factory concentrations and aren't proofed to be stable over time. Every reference gas must therefore on regular interval be calibrated in an accredited lab.

SOP 2.9. Calibration of the reference gasses

1. **When:** Following scheme should be used
   - **a.** SO2 and NO reference gas
     - Minimum every 4 months
     - Before a campaign (after longer periods of inactivity)
     - At the end of a campaign (if last calibration was more than 2 months ago and next calibration is more than 2 months away)
     - In case the calibrations show a significant error (difference of more than 10%)
     - Before using the cylinder in the field for the first time
     - In case the active cylinder in use has a pressure <50bar the next cylinder in line should be calibrated
   - **b.** CO2 reference gas
     - Minimum every 12 months
     - Before a campaign (after longer periods of inactivity)
     - At the end of a campaign (if last calibration was more than 6 months ago and next calibration is more than 6 months away)
     - In case the calibrations show a significant error (difference of more than 10%)
     - Before using the cylinder in the field
     - In case the active cylinder in use has a pressure <50bar the next cylinder in line should be calibrated
   - **c.** Zero gas
     - After delivery

Note: In the beginning of the year the planning of the cylinders is drafted and agreed upon with the lab, these dates are also put in the SURV agenda. When the cylinders are due for calibration as they are out of boundary, this is indicated in the "SQMS-Follow-up.xlsx" file, and in that case a calibration might be advanced in collaboration with the lab

2. **Equipment:**
   - **a.** Office chart
   - **b.** Cylinders

- **c.** Regulators
- **d.** Aluminium case with protective material
- **e.** Adjustable spanner
- **f.** 7/16 wrench
- **g.** Straps

3. Time: 1-2 days

4. Methodology

- **a.** When time is due, the regulator is disassembled from the cylinder and put in the aluminum transport box and fully covered with protective material
- **b.** The cylinders are disassembled from the chart
- **c.** The cylinders and regulators are transported to MUMM premises in Brussels (see 5.7 Transport of reference gasses)
- **d.** The cylinders and regulators are stored at the storage room (see 5.6 Storage of reference gasses)
- **e.** The day of the calibration, the cylinders and regulators are brought to the lab using the office chart, make sure to use a (simple) strap to attach the cylinders to the office chart.
- **f.** The regulators must be assembled on the cylinders prior to the calibration
- **g.** A leak test should be done after assembling the regulator (see 6.4.4 Regulator)
- **h.** Note down the pressure before calibration
- **i.** The calibration of the reference gasses is fully executed by the lab, assistance may be provided with the positioning of the bottles and the purging
- **j.** Write down the pressure after calibration
- **k.** After calibration a calibration certificate is provided by the lab
- **l.** Write the date, concentration and pressures on the cylinder
- **m.** The trace elements
  - When a cylinder is used for the first time traces for the other gasses should be measured
  - For CO_2 measure NO and SO_2,
  - Write down trace levels on the cylinder
  - Write down the traces in the header of the specific gas sheets.
  - For NO, the NOx concentration should be measured every time
- **n.** Enter the calibration information in the “SQMS-Follow-up.xlsx” file in the “GAS CAL” sheet
- **o.** Transport the cylinders back to Deurne (see 5.7 Transport of reference gasses)
- **p.** Remount the cylinders on the chart
- **q.** Install the regulators
- **r.** Perform a leak test after installing the regulators on the cylinders (see 6.4.4 Regulator)
- **s.** In case the drift of the gas cylinder was more than 10% a hardware calibration should be executed (see Chapter 4 Hardware calibrations)
- **t.** When calibration is reset (see step 21), **NO** software calibration is needed for the first flight after a hardware calibration (for SO_2 and CO_2).
- **u.** Remove the old software calibration file
  - On MUMM-LOG-PC

- Close TCP log
- Close watchdog
- Close IGPS present
- Close watchdog
- Close IGPS present
- Go to C\IGPS\TCP-LOG
- Look for the CALLIBRATION.txt file
- Change the file name to CALLIBRATION_DATE(XX-XX-XX).txt file
- Reopen the watchdogs
    - i. C\IGPS\Watchdog-IPGS
    - ii. C\IGPS\Watchdog-TCP-LOG
- Check if the calibration factors in IGPS present under utilities are all 0 (offset) and 1 (slope) and the gasses under the SNF graph are "NOT SET"

v. In case the previous step did not work a software calibration must be performed (see Chapter 3Chapter 3 Software calibrations)

	A	B	C	D	E	F	G	K	L	M	N
1	**Calibration of gas cylinders**										
2	**Sheet**	**CO2-1 (1)**	**CO2-1 (2)**	**CO2-1 (3)**	**CO2-2 (1)**	**CO2-2 (2)**	**CO2-2 (3)**	**SO2 (4)**	**SO2 (5)**	**SO2 (6)**	**SO2 (7)**
3	**Cylinder nr**	LOMP31M	APE 10306	LOMP2G6	L001YGK	72583	LOMP2T8	D3CL1R7	D2RUSYN		
4	**Gass**	CO2	CO2	CO2	CO2	CO2	CO2	SO2	SO2		
5	**Volume**	20l	10l	20l	20l	10l	20l	10l	10l		
6	**Factory**	368.7 ppm	390 ppm	366.9 ppm	411.2 ppm	440 ppm	409.5 ppm	449 ppb	432 ppb		
7	**Drift**	0.26%	0.25%	0.00%	0.94%	0.23%	0.48%	2.39%	0.68%		
8	**Date**										
9	04/08/2016										
10	05/08/2016	368.7		366.9	411.2		409.5				
11	10/08/2016		390								
12	16/08/2016					441					
13	07/09/2016										
14	22/10/2016	379	396	376	426	438	421				
15	08/08/2017							449	432		
16	21/09/2017	379	397	376	426	437	419	381.7	368.4		
17	21/02/2018	378			422			384.8			
18	21/06/2018							394	370.9		

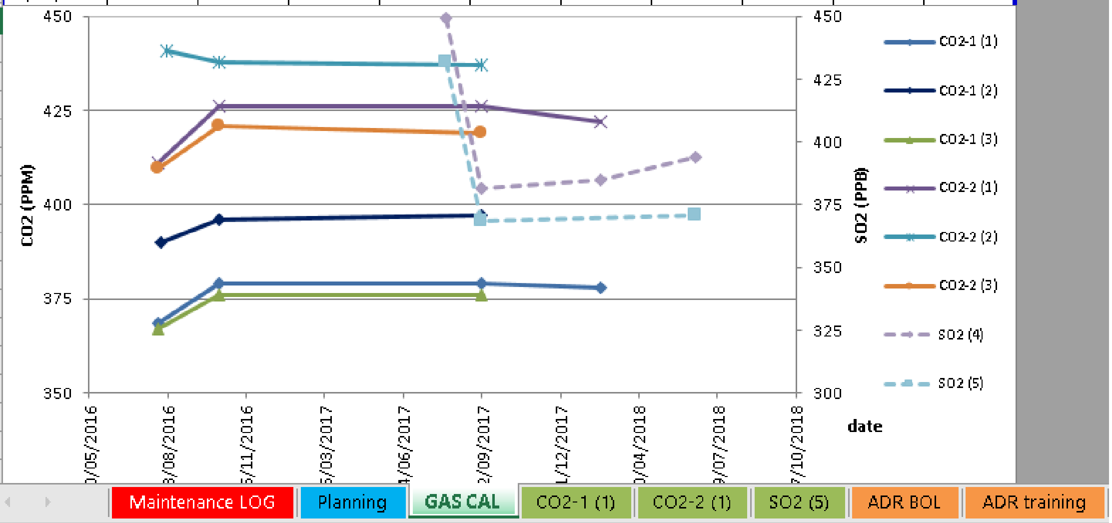


Figure 82 SQMS-Follow-up.xlsx file with cylinder overview (GAS CAL) sheet, active cylinders sheets, ADR sheets and LOG sheet.

5.5.1 Certifications

An ISO6414 certification should be provided for the calibrations of the reference gasses. This certificate should include:

- Certification number
- Date
- Serial number of cylinder
- Calibration method
- Indicated concentration
- Actual concentration
- Uncertainty (with 95% CI or factor k = 2)
- Environmental Conditions (temperature, pressure)
- Stamp or signature from the lab or manager
- Guaranteed period

Note: For the CO2 reference gasses, no accredited governmental lab is available that is able to provide certificates, but the lab of the Brussels Environmental Agency is nevertheless able to perform the calibrations (without providing a certification).

5.6. Storage of reference gasses

Following rules apply for the storage of the reference gasses:

- Gas cylinders should be stored in dry dark (heated) room.
- Room should be locked
- A warning should be placed on the door that cylinders are stored in the room
- The maximum volume should not exceed 120 volumetric l
- Temperature range from 10-30°C.
- Empty cylinders can be stored outside in a dedicated area
- Full cylinders that are not used in the chart should be attached to the wall
- Cylinders in use should be attached to the chart with strap
- When a new cylinder is used this should be marked on the bottle (and the plastic indicator “full” should be removed)
- If the cylinder is empty this should be marked on the bottle (and the plastic indicator “in use” should be removed)

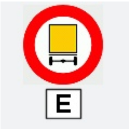
Note: Gas cylinders are stored in room 418 at Gulledelle 100, 1200 Brussels, empty bottles are stored on the right side, full bottles are stored left side.

5.7. Transport of reference gasses

Reference gasses should be transported according to the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR). An exemption to the general conditions for transport applies for small loading (ADR1.1.3.6), following rules apply:

- CO2 Class: 2A Non-flammable, Transport category 3 (maximum volume 1000L)
- SO2 Class: 2TC Toxic corrosive, Transport category 1 (maximum volume: 20L)

- NO Class: 2TOC Toxic oxidizing corrosive, Transport category 1 (maximum volume 20L)
- A bill of loading should be available at the driver's seat, a printout can be made from SQMS-Follow-up.xlsx, under "BOL" sheet, it suffices that the driver details are filled in and the cylinder reference are selected from the drop-down list to generate a bill of loading.
- General training for the driver should be performed, with records (ADR 1.3.2), the records of the training are available in the SQMS-Follow-up.xlsx under "ADR" sheet.
- A fire extinguisher of 2 kg dry powder should be on board (ADR 8.1.4.2)
- Regulators should be removed from cylinders, valves should be closed and cylinder protective top cap should be in place.
- Cylinders should be stowed properly (perpendicular with driving direction and attached with heavy duty straps. Make sure the cylinders are not able to role under the straps by using the cylinder holder tool, especially when only 1 or 2 cylinders are transported (see Figure 83).
- No access to tunnels with category E with pressurized cylinders on board (in Belgium: Small Ring Brussel and tunnel under Van Praet bridge)



- Optionally a sign stating the transport of gas cylinders can be placed behind the window.

SOP 2.10. Attachment of cylinders in car

1. See Figure 83 for attachment of layout of the cylinders (colours are only illustrative)
2. Take the loose end of the strap and follow the numbers on the layout, keep the buckle at start position.
3. Turn the strap around the cylinder (4) when only 1 or 2 cylinders are transported.
4. Unlock the buckle, turn on the small lever in the big handle and pull the big handle forward
5. Put the loose end in the opening (enter from bottom side of the buckle)
6. Pull tight on the strap end (min 20 cm loose end is required to pass through the buckle)
7. Tighten buckle by alternatingly pulling big handle forwards and backwards.
8. When strap is tightened, put big handle backward and lock handle (pull small lever back and push big handle backwards).

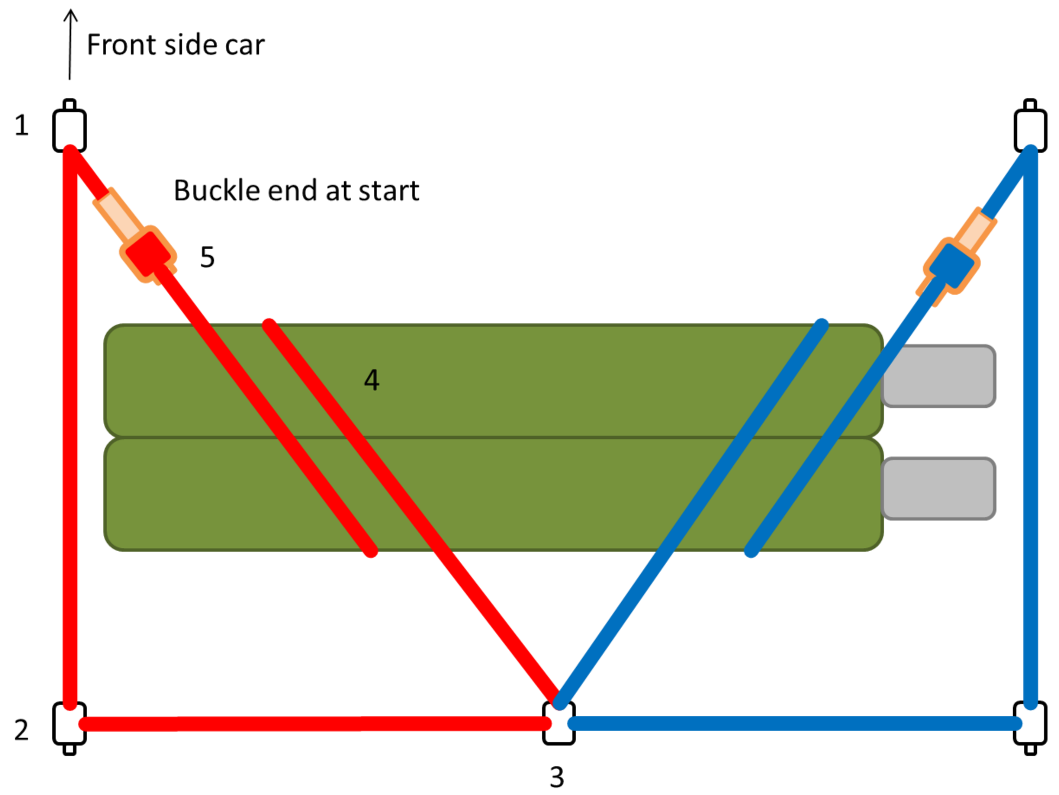


Figure 83 Attachment procedure for transporting reference gas cylinders in the trunk of a vehicle.

Figure 84 office chart, strap with ratchet (for attachment on chart and in car) and simple straps

Bill of loading - ADR

Royal Belgian Institute of Natural Sciences
OD Nature - Scientific Service MUMM
Gulledelle 100
1200 Brussel

Driver ________________________

Carlicense ________________________

Date ________________________

Cylinder	Cylinder nr	Content	Concentration	Filling Gas	Volume
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Sum Category 1: Sulphurdioxide, Class: 1A Toxic corrosive gasses (max 20l)					0l
Sum Category 3: Carbondioxide, Class: 2A Non-flammable gasses (max 1000l)					0l
Total (max 1000l)					l

Exemption to the general conditions for transport of dangerous good by road applies for small loading (ADR1.1.3.6):
- Make sure there is appropriate ventilation,
- all cylinder should be properly closed (valve, cap and cover) and attached,
- the maximum volume per transport category and total maximum volume should not be exceeded,
- driver must be trained according ADR 1.3.2,
- no access in tunnels with category E,
- a fire extinguisher of 2 kg dry powder must be on board (ADR 8.1.4.2).

Signature ________________________

Figure 85 Bill of loading to be filled in, signed and stored in the front of the car

CHAPTER 6. PREVENTIVE SERVICING

This chapter describes preventive service operations for the different components of the sniffer sensor. For more detailed information look at the dedicated manuals of the different components, available under the "QMS>>QA_MANUAL>>Sensor" manual folder. All servicing operations should be executed by qualified persons. Beside the dedicated component service, a holistic sniffer sensor service should be executed by the sensor developer, FluxSense.

6.1. Internal sniffer sensor components

Twice a year the sniffer should be demounted from the aircraft and opened for service operations, this can be combined with the SO2 hardware calibration (see Chapter 3).

SOP 2.11. General preparation sniffer servicing: demounting sniffer

1. When:
2. General Equipment:
    a. Ground Power UNIT (GPU)
    b. Optional power cord to bypass AC power
3. Tools: wrenches 3/8, 7/16, electrical screwdriver, Torx (T10), Hex (3mm), Hex ()
4. Duration preparatory work: 60 min
5. Duration of bi-annual service and hardware calibration: 1 day
6. General preparation:
    a. In case maintenance on the Licor is executed make sure to make a configuration backup (see 6.1.1 LICOR 7200RS)
    b. Unmounting sniffer from sniffer AC
        - Untighten all screws of upper and from brackets (3/8") of sniffer rack
        - Loosen screws of SLAR (3/8")
        - Slide Sniffer 20 cm to the front
        - Disconnect all wiring from the sniffer side and use covers to protect the connectors
        - Disconnect all tubing, install caps to protect all gas inlets and outlets (also on open tubing)
        - Disconnect the tubing to the filter box, install caps, remove the filter box (Velcro)
        - Remove sniffer and place sniffer on a table (at the cockpit door or in the office)
7. Unmounting NOx
    a. Loosen straps
    b. Disconnect wiring and tubing (use covers to protect connectors)
    c. Remove NOx sensor
8. On sniffer: to access the top compartment (LICOR, Thermo, NOx pump, Bronkhorst)
    a. Open top hatch cover of the sniffer by removing top screws on the sides of the sniffer, don't forget to remove the screws under the quick release plate
    b. Be careful to disconnect the connector from the fan wiring (back left corner)
    c. Connect all wiring
9. To access the bottom compartment (MUMM LOG PC, Power converters, Ethernet hub AIS+GPS receiver, SO2 and CO2 air pump, buffer)

   - **a.** Turn sniffer upside down
   - **b.** Open bottom hatch cover of the sniffer by removing bottom screws on the sides of the sniffer, don't forget to remove 4 screws on the front bottom side of the sniffer
   - **c.** Be careful to disconnect the connector from the fan wiring (back left corner), when replacing make sure the wiring is positioned behind the buffer
   - **d.** Connect all wiring (accept ARINC wiring – J251)

10. To access the NOx sensor

   - **a.** Remove the front protection panel (Allen key, nr 4)
   - **b.** Remove the bolts on the side
   - **c.** Slide backwards top panel and remove panel

⚠ Work on the internal component can only be done by qualified persons, an antistatic should be used in all times when touching internal components from the Thermo 43i TLE

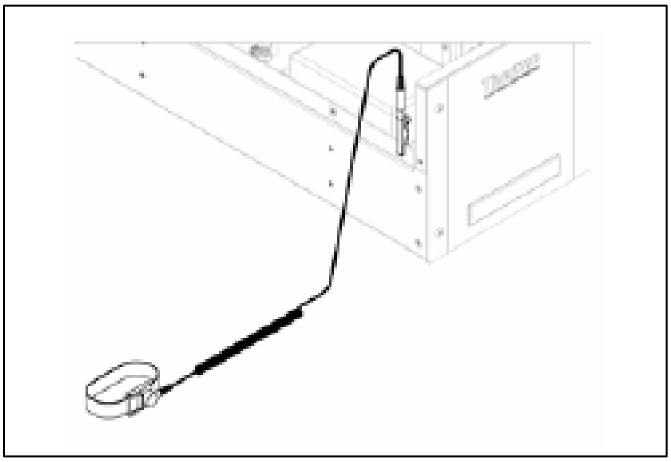


Figure 86 Use antistatic when operating on the internal components

6.1.1 LICOR 7200RS

A 2-year maintenance cycle is applicable for the sensor, this consist of following operations

- Cell Cleaning
- Factory calibration
- Thermocouple replacement
- Replacing the IR source (every 6 years)

Special maintenance can be done by Catec. More information about the Licor system including software, manuals and configurations can be found in the Thermo folder under the FluxSense sniffer folder.

Note: The general maintenance includes typically the update of the LICOR7200RS with the latest GHG software and embedded software. The latest embedded software version fully compatible with the IGPS software is software version 8.0, the LICOR should therefore **not be updated** before special approval from FluxSense, as the added verbose mode in the embedded software from version 8.5 onwards are resulting in a non-stable data output, resulting in a 10 seconds data blackout once per minute. It is advised to always use the same software version for the embedded software as the GHG software.

To access the Licor system for maintenance the Sniffer sensor has to be opened, therefore this can be optimally combined with the Thermo maintenance or filter replacement.

SOP 2.12. To access the Licor system for maintenance and inspections

1. Before conducting any maintenance on the Licor sensor, a configuration backup file needs to be created as backup, this has to be done before demounting the sniffer from the aircraft.
    - **a.** Connect power extension cord
    - **b.** Power on GPU
    - **c.** Plug in GPU to external AC power bus
    - **d.** In cockpit Switch on “External power supply”
    - **e.** Switch on “utility”
    - **f.** Switch on “survey power”
    - **g.** Check sniffer circuit breaker in cockpit (must be pressed down)
    - **h.** Master switch on sniffer box needs to be put in upward position
    - **i.** Switch on sniffer with remote switch in cabin (at intercom jacks)
    - **j.** Check circuit breaker on emergency sniffer battery (must be pressed in)
    - **k.** Connect laptop with Thunderbolt cable
    - **l.** Switch off all other non-used network adapters (WIFI and Ethernet) in “Network and sharing center” >> “Change adapter settings”
    - **m.** Connect to MUMM_LOG_PC using TeamViewer (V12) use 192.168.1.9 (make sure TeamViewer accepts LAN connections) and pwd: “mumm”
    - **n.** Go to LICOR software GHG V8.0 (on MUMM_LOG_PC)
    - **o.** Go to Config Files>>Safe as
    - **p.** Safe all settings as configuration file and store the file under
    - **q.** QMS>>QA_Follow-up>>Configuration files>>Licor
2. Shut down sniffer
3. Demount the sniffer and open the top cover (see 6.1 Internal sniffer sensor components)
4. The LICOR is located on the right side of the Sniffer (see **Error! Reference source not found.**)
5. To access the interface (Licor 7550) open the Licor 7550 cover (small bolts)
6. If necessary the sensor head (LI-7200 RS) can be disassembled and shipped to Catec for inspection:
    - **a.** Mark the position of the fittings and cables to the Sensor head
    - **b.** Disconnect the Swagelok intake connectors left side
    - **c.** Disconnect the Swagelok outlet connectors (cross)
    - **d.** Disconnect the 2 cables between the LI7200 and the LI7550 unit (turn counterclockwise)
    - **e.** Disconnect the small pressure sensor tube
    - **f.** Loosen the metal straps with a Philips screwdriver
    - **g.** Carefully remove the sensor from the frame
7. Use appropriate protection when shipping the sensor to Catec
8. Turnover time can be several weeks

⚠ Opening the Licor sensor head can only be done by Catec or FluxSense

SOP 2.13. To reinstall the Licor system after maintenance by Licor

1. Open the top cover (see Chapter 3)

2. Reinstall the Licor 7200RS sensor head:
   a. Carefully put the sensor in the right metal strip, loosen the metal strap further with a Philips screwdriver if necessary
   b. Slide the sensor backward, be careful with the cabling
   c. Slide over the front metal strip, loosen the metal strap further with a Philips screwdriver if necessary
   d. Check the matching of the markings of the straps on the sensor and tighten both straps with Philips screwdriver
   e. Mark the position of the fittings and cables to the Sensor head
   f. Connect the small pressure sensor tube
   g. Connect the 2 cables between the LI7200 and the LI7550 unit (turnclockwise)
   h. Connect the Swagelok outlet connectors (cross), tighten until the marking
   i. Connect the Swagelok intake connectors (left side) until the marking
3. Close the top cover of the sniffer sensor

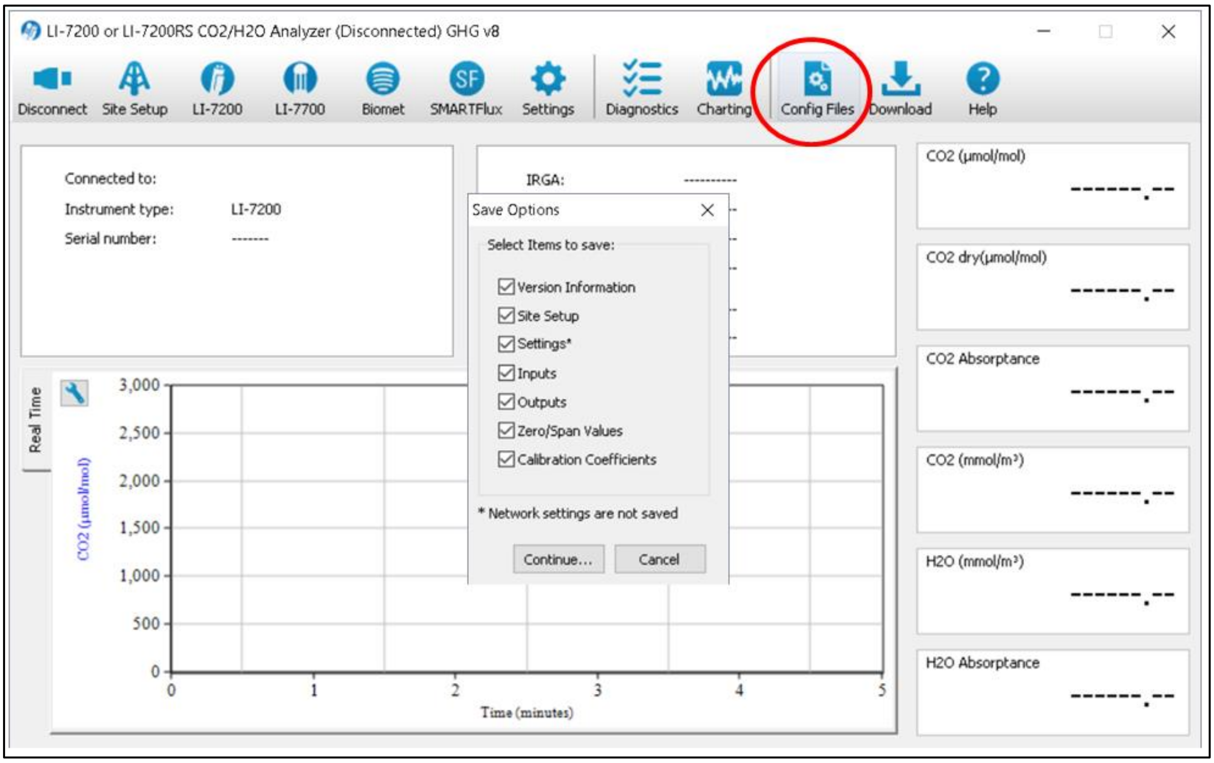


Figure 87 Save all setting of the sensor as Configuration file

6.1.2 THERMO 43i TLE

Periodic maintenance should be performed to ensure a proper working of the sensor, as the Thermo sensor is adapted for the sniffer system, not all of the general maintenance operations are applicable. For all maintenance on the Thermo sensor of the sniffer sensor the top side of the sniffer needs to be made accessible (see 6.1). The maintenance should optimally be executed in the office or workshop and not with the sniffer in the aircraft. Following operations should be performed on 2 year basis:

See Annex B - Block Diagram for the structure of the Thermo 43i TLE menu's.

SOP 2.14. Thermo 43 bi-annual service

1. Connect Thermo Display panel

   - **a.** Connect the 34 pin 2.54 spacing IDC ribbon cable (IEI 32200-000017-RS) from Thermo front panel to THERMO motherboard (J18) (or use the Thermo box with cable to J251)
   - **b.** Disassemble the pitot tube from the aircraft and connect the pitot-tube to the air-inlet of the sniffer (7/16 wrench)

2. POWER on sniffer bypassing AC power
   - **a.** Connect sniffer power cable to GPU (Mil connector)
   - **b.** Connect the sniffer power cable to the sniffer (J211)
   - **c.** Put a jumper in the white connector (Figure 88)
   - **d.** Connect GPU to 220VAC socket
   - **e.** Switch on main power switch on sniffer (switch must be faced upward)

3. Wait 45 minutes or check alarm (chamber temperature must be between 43 and 47°C)
   - **a.** Press on the button underneath the alarm symbol on the panel
   - **b.** Check the alarm counts (must be 1, only flow should provide an alarm as the flow meter is not installed in the sniffer sensor)

4. Check calibration factor (Figure 89)
   - **a.** Click on menu
   - **b.** Go to Calibration factor by using click enter
   - **c.** In case the calibration factor is <0.9 and inspection of the sensor might be required (to be done by Fabricom)

5. Check diagnostics (see Figure 90, Figure 91, Figure 92)
   - **a.** Click on menu
   - **b.** Go to diagnostics by using click enter
   - **c.** Go to Voltages >> Interface board >> Flash supply should be <950V
   - **d.** When lamp voltage is out of boundary (>1050V) this can be lowered manually (to be done by Fabricom)
   - **e.** Go to temperatures, internal and chamber temperature should be 40-60°C
   - **f.** Check Lamp intensity (<95%)
   - **g.** Check for regular clicking sound (if not present, lamp should be replaced)

6. Clean Optical Bench
   - **a.** Disconnect tube fittings, make sure to remove the pressure sensor to avoid damage
   - **b.** Use air compressor to clean the optical bench
   - **c.** Reconnect tube fittings
   - **d.** Check for leaks by doing leak test (see 6.1.9)

7. Perform factory (hardware) calibration (see 4.2)

8. Lamp replacement procedure
   - **a.** When consequent drift is observed, when lamp intensity is either too low (<50%) or too high (>95%) or when clicking sound is not stable, the lamp and/or lamp trigger may need to be replaced
   - **b.** Before replacing lamp, the lamp trigger should be replaced as this often already solves the problem
   - **c.** Replacement of the Lamp and lamp socket should be performed by accredited Thermo servicing company or FluxSense.
   - **d.** To replace lamp and /or lamp (flash) trigger:
      - demount the measurement chamber from the bench (Allen key nr 4)

- unscrew the retaining screw on the lamp socket in front of the flash trigger
- the lamp socket can be removed from the sensor head by unscrewing 4 screws
- pull the lamp + flash trigger out of the lamp socket
- remove the lamp from the trigger
- put the new lamp in the trigger, or put the old lamp in the new trigger
- reinstall the lamp + trigger in the lamp socket
- reattach the socket to the sensor head
- reinstall the retaining screw
- In case the trigger is replaced, the wiring of the new trigger must be connected
- Reinstall the sensor head to the bench

e. Follow the installation procedure described in the Thermo manual for the configuration of the lamp

9. Replace any other malfunctioning cables, tubing or components

Maintenance can be provided by Fabricom. An arrangement must be made 2 weeks in advance, Fabricom can perform, sensor inspections, factory calibrations, component replacement (all components are in stock).

More information about the Thermo system can be found in the Thermo folder under the FluxSense sniffer folder.

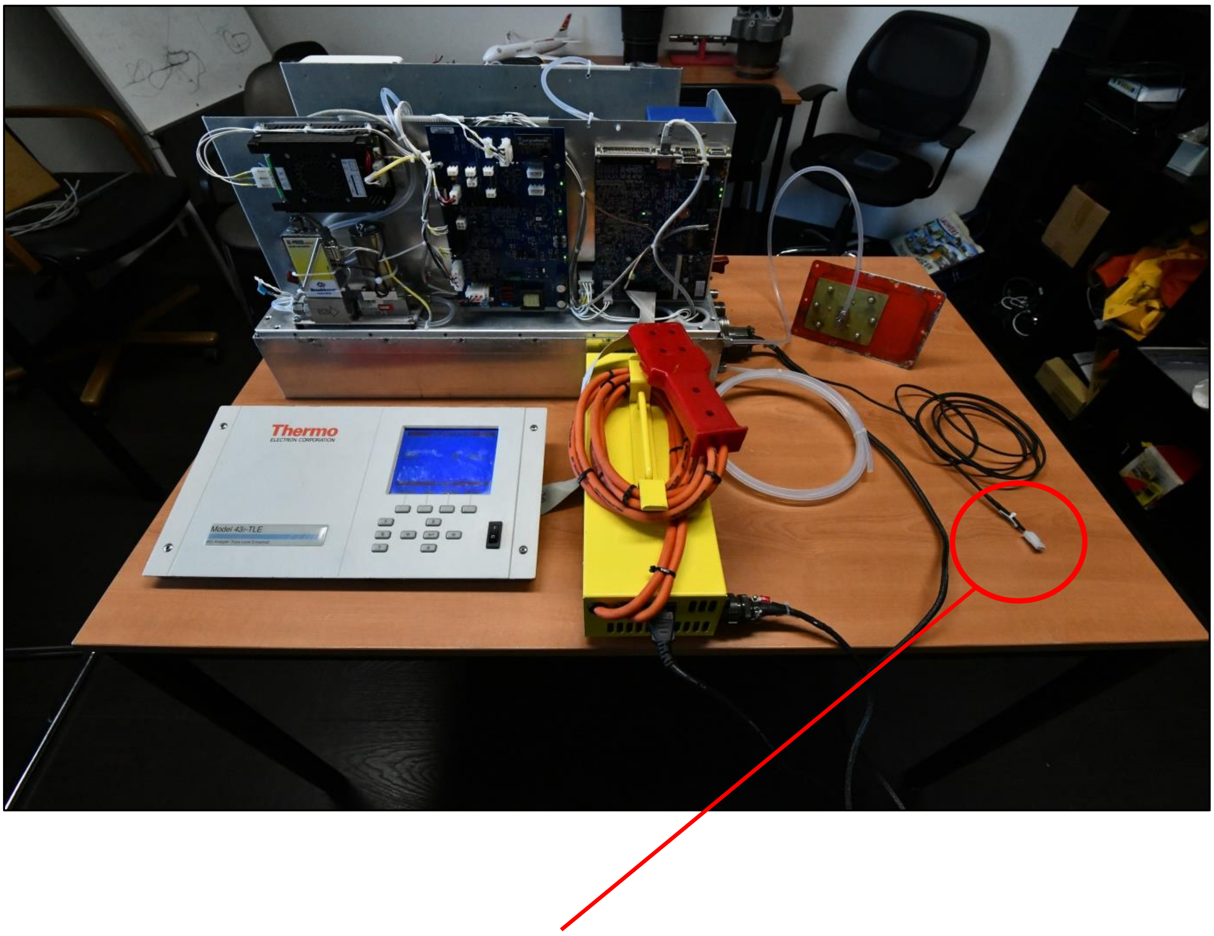


Figure 88 Setup of Thermo maintenance, with Pitot-tube, GPU, Thermo front panel and jumper in white connector

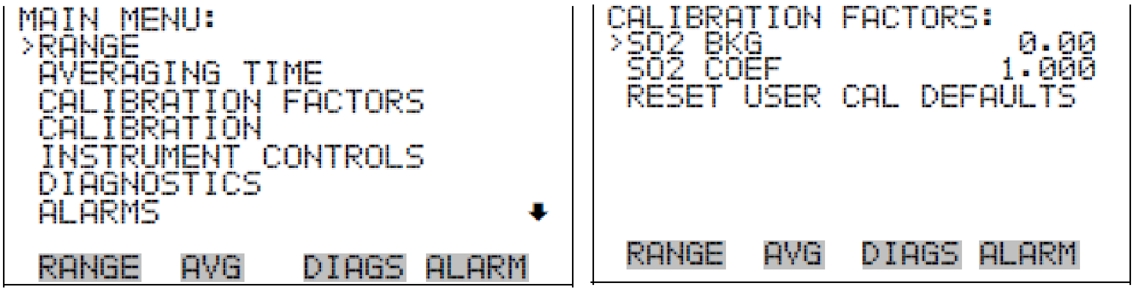


Figure 89 Main menu and calibration factor menu

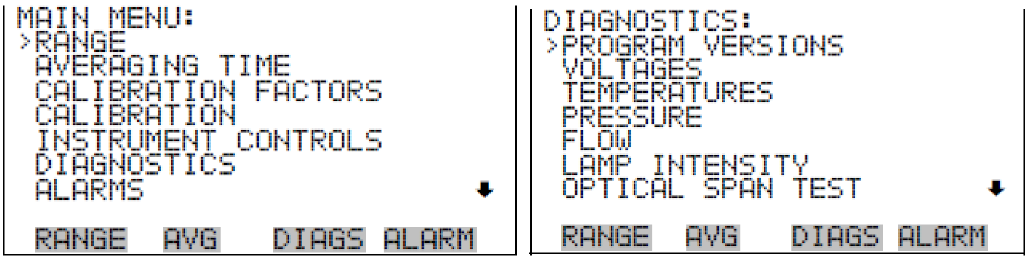


Figure 90 Main menu and Diagnostics Menu

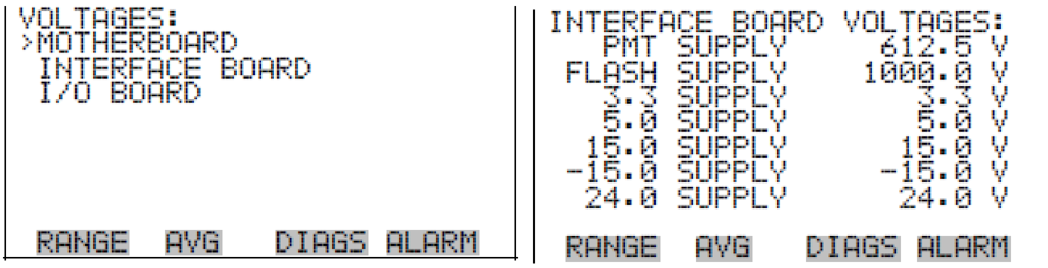


Figure 91 Diagnostics voltages – interface board voltages

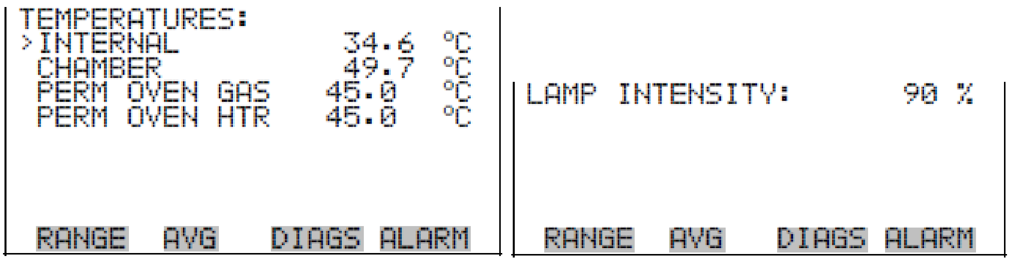


Figure 92 Diagnostics menu, temperatures (internal and chamber >40°C) and lamp intensity (<95%)

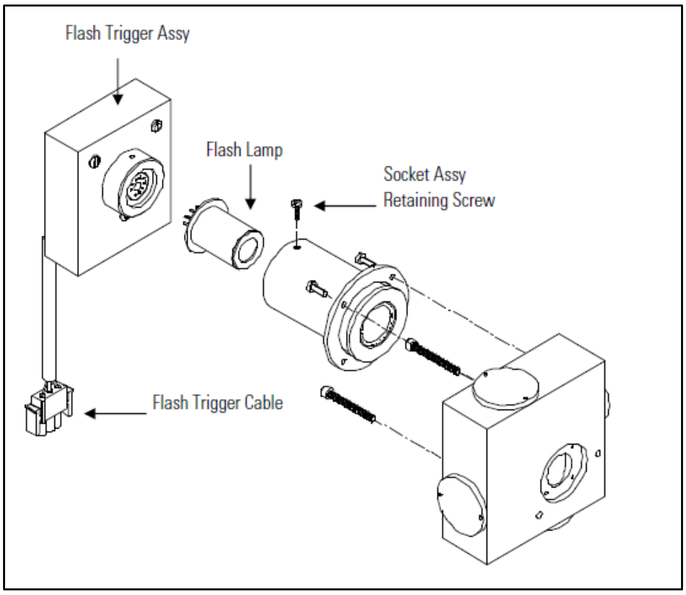


Figure 93 Lamp replacement

6.1.3 Ecotech Serinus 40

The Ecotech Serinus 40 should undergo a bi-annual maintenance. This maintenance should be executed by a licensed maintenance organization. In Belgium ETS is able to conduct this maintenance (contact person Roger van Uden - roger@etserv). During this maintenance, a cleaning is performed as well as flow calibration a hardware calibration and a filter replacement.

6.1.4 Bronkhorst regulators

Both flowmeter and pressure regulator from Bronkhorst are installed. No information is available about the maintenance. The Bronkhorst meters may require recalibration or replacement when malfunctioning, make sure to use following hardware settings when installing a new instrument.

- Flowmeter: LSD:1; MSD:0
- Pressure regulator: LSD: 0 MSD: 2

The Bronkhorst regulators are connected to Ethernet via a RS232 to Ethernet connection. Following port sand IP addresses have been used

- Flowmeter:

  10. Serial Port: COM 4
  11. Baud rate: 38400
  12. IP: 192.168.1.102 (port 1471)
  13. Serial Nr: SNM16206036A

- Pressure regulator:

  14. Serial Port: COM 4
  15. Baud rate: 38400
  16. IP: 192.168.1.106 (port 1470)
  17. Serial nr: SNM12205648E
  18.

Bronkhorst High-Tech B.V. FLOW-BUS DDE-server

Date: 2018-03-26 Time: 13:59:45

FlowDDE V4.74

FLOWBUS.DLL V6.38.0.1

Database V3.73

System configuration overview:

chan node proc id module number description

001 001 001 07 DMFC SNM16206036A Digital Mass Flow Controller

002 002 001 09 DEPC SNM12205648E Digital Pressure Controller

To access the Bronkhorst regulators, use the dedicated Bronkhorst software FLOWDDE and FLOWPLOT. Output can be used for limited troubleshooting. For more information on the Bronkhorst flowmeters, manuals, software and configuration files see Bronkhorst folder under the Fluxsense Sniffer folder.

⚠ Reinstalling and configuration the Bronkhorst regulators should be done by FluxSense

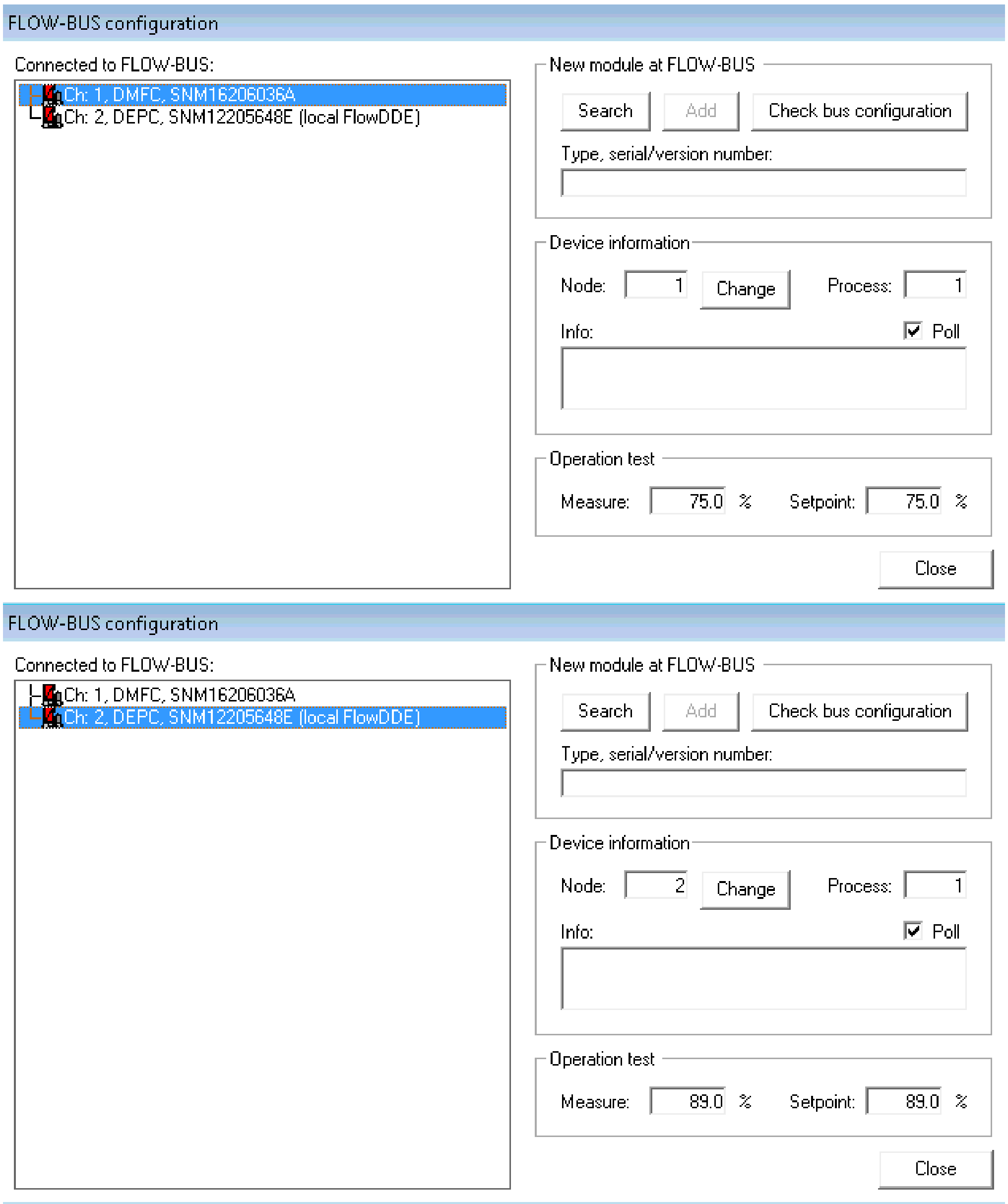


Figure 94 Bronkhorst regulators flowbus configuration

6.1.5 MUMM_LOG_PC

General computer maintenance should be executed on the MUMM_LOG_PC (ZOTAC) from time to time (virus test, cleaning up of log files, backups, clone of hard drive). The IGPS software on the MUMM_LOG_PC should be updated after having been thoroughly tested on a client station. For most computer maintenance the sniffer sensor does not have to be disassembled from the aircraft, only for the replacement of the HDD (or SSD) the sniffer must be opened

SOP 2.15. MUMM-LOG-PC maintenance

1. When:
    a. Update: as soon as a new stable version is available from FluxSense
    b. General maintenance: Every 12 months
    c. HD replacement: After failure
2. General Equipment:

   a. Ground Power UNIT (GPU)
   b. Optional power cord to bypass AC power
3. Software update
   a. Connect GPU to the AC
   b. Close the Watchdogs, TCP log, IGPS present, and all other files and programs
   c. Make a backup of the program files, log files and emission files from the IGPS folder from the LOG_PC (to 25-Sensor-Data/Sniffer/MUMM_LOG_PC Seafile)
   d. Copy the latest IGPS software to the IGPS folder on MUMM_LOG_PC
   e. Remove or rename the old “AISPresent.exe” version
   f. Rename the new version to “AISPresent.exe”
   g. Shut down the MUMM_LOG_PC
   h. Power off the sniffer, wait 10 seconds and power on the sniffer
   i. Reboot the sniffer

The original HDD hard drive of the sniffer sensor system has been replaced by a faster and more reliable Samsung EVO 850 2.5 inch SSD of 1TB (SSD1). The previous hard drive was cloned prior to this operation. On annual basis a clone of the installed SDD to a second Samsung EVO 850 2.5 inch SSD of 1TB (SSD2) should be made:

SOP 2.16. To clone SSD

1. Place SSD-2 in Kingston drive case and connect to USB port on the back of the sniffer
2. Power on the Sniffer sensor
3. Connect to the MUMM_LOG_PC using TeamViewer
4. Close all programs and files
5. Open Samsung Data-Migration software
6. Run the cloning software, make sure both drives area visible, select start (cloning will take 30 min)
7. Shut down the Sniffer sensor
8. Disconnect the SSD

Note: Do not override the original HDD, this should be kept for safekeeping,

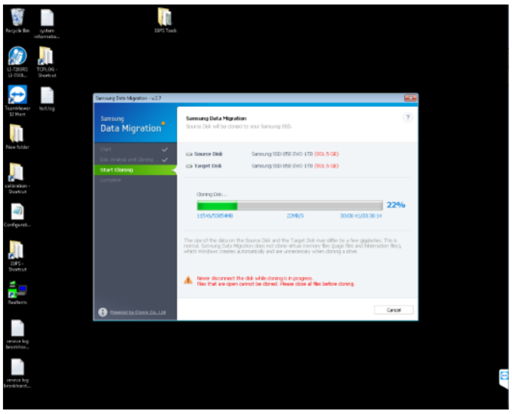
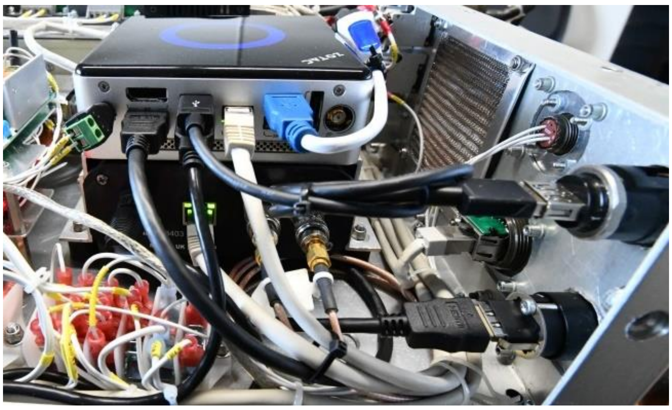



Figure 95 Samsung data migration software and location MUMM_LOG_PC on top of AIS+GPS receiver

In case of SSD failure or significant software issue, the SSD1 can be replaced with SSD2. The hard drive is located under the MUMM_LOG_PC to replace the SSD follow following procedure:

SOP 2.17. Replacement SSD

1. For this procedure the Sniffer sensor should be disassembled and bottom part needs to be opened (see 6.1 Internal sniffer sensor components)
2. Mark all cabling from the MUMM_LOG_PC and AIS+GPS receiver (tip: make a picture)
3. Disconnect all cabling from the MUMM_LOG_PC and the AIS+GPS receiver
4. Unscrew the fixation for the MUMM_LOG_PC +AIS (Hex 7)
5. Remove the AIS+GPS receiver (Hex 8)
6. The hard drive is located under the MUMM-LOG-PC, use PH1 screwdriver to remove SSD
7. Mount the other SSD
8. Replace the AIS+GPS receiver
9. Reinstall the MUMM_LOG_PC and AIS+GPS receiver
10. Reconnect all wiring

In addition to regular maintenance the MMSI MID country codes and Keel Laying date should be updated on annual basis or when crashes or commonly observed. See Section 3 for more information on how to update the data reference files.

6.1.6 AIS+GPS receiver

The AIS+GPS receiver used in the sniffer is a Comar SLR200NG receiver. A VHF receiver is installed on the belly of the aircraft and connected to the ASP connector panel (TNC), a GPS receiver is installed on the top of the aircraft and connected to the ASP connector panel (TNC). The receiver is located in the bottom compartment of the sniffer underneath the LOG-PC. If AIS+GPS is malfunctioning a troubleshooting (see 7.6 Problems with AIS+GPS receiver) can be done to identify the issue. The unit, cabling and/or antennas may need to be replaced, in case of antenna or cabling issues, this has to be done by ASP. In case of a unit failure, the needs to be replaced by a new Comar SLR200NG unit, this can be done by either MUMM or FluxSense. Note to remove the AIS+GPS receiver, special care should be made with the MUMM_LOG_PC as it is required to demount the MUMM_LOG_PC to change the AIS+GPS receiver (see above).

Note: replacement of the AIS+GPS unit should only be done when the Sniffer sensor is shut down and fully disconnected from the aircraft.

6.1.7 Arinc

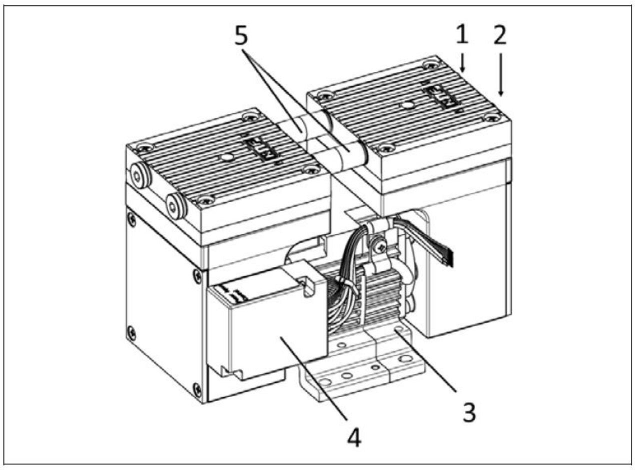
An Arinc converter is installed in the sniffer (ARINC ADC 20160815), no maintenance is foreseen. Ad hoc replacement in case of failure can be executed by FluxSense. In case of failure a first inspection can be carried out by MUMM to inspect the wiring and the power supply. Also the 5 volt RS232-Ethernet converter can be inspected by MUMM.

6.1.8 Air pumps

The air pumps perform a crucial part in the sniffer as they provide the airflow needed for the sensors to measure the gas concentrations. Air pumps have moving parts and are therefore more susceptible to wear and break-down and must be closely watched.

Pump 1 used for the SO2 and the CO2 sensors and pump 2 used for the hydrocarbon kicker are from the same line and use the same diaphragms

1 Outlet (pressure side)
2 Inlet (suction side)
3 Motor
4 Motor controller
5 Pneumatic connection



1 Outlet (pressure side)
2 Inlet (suction side)
3 Motor controller
4 Motor

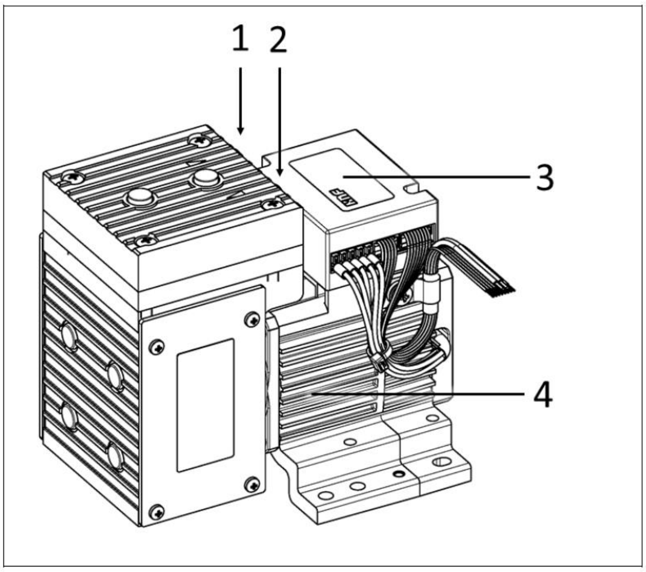
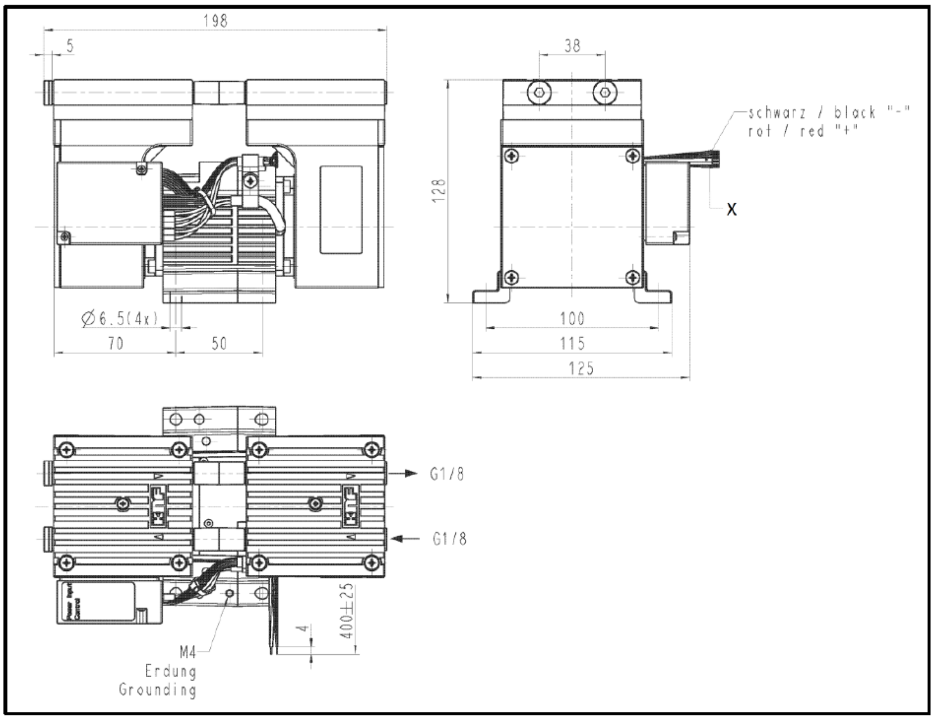


Figure 96 Pump 1 (N 838.1-2 KNDC-B) and Pump 2 (N 838.1 KNDC-B) connection



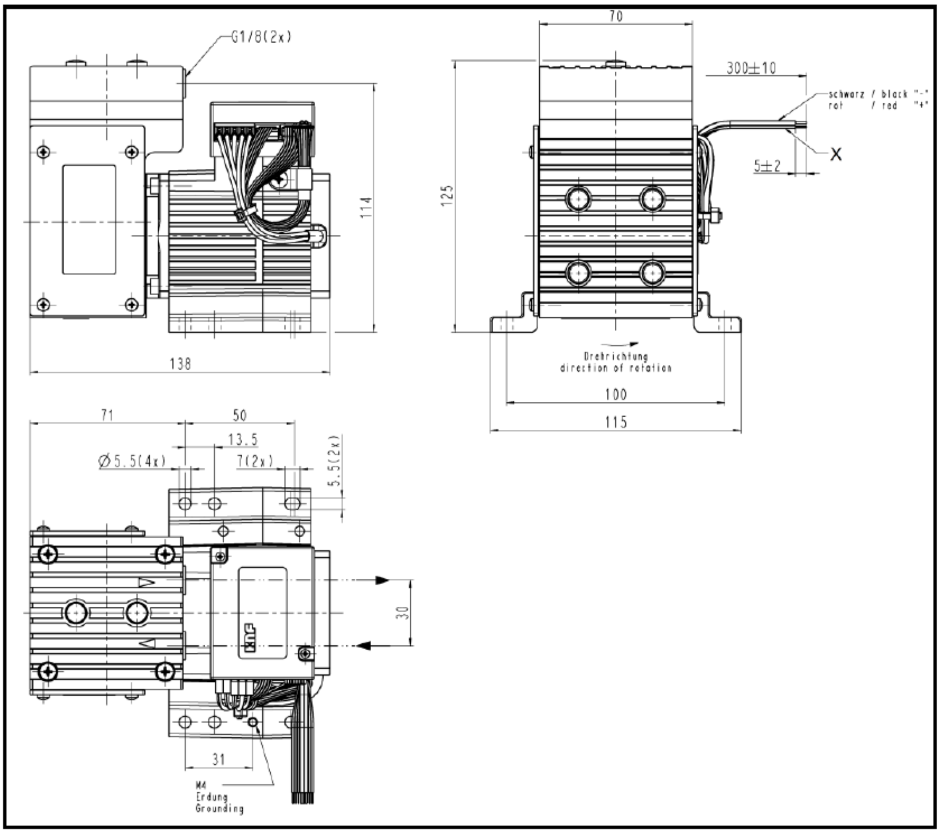


Figure 97 Diagram of the N 838.1-2 KNDC and N 838.1 KNDC pump, note that the pump used in the sniffer sensor is a special order with the head turned 90° counter clockwise

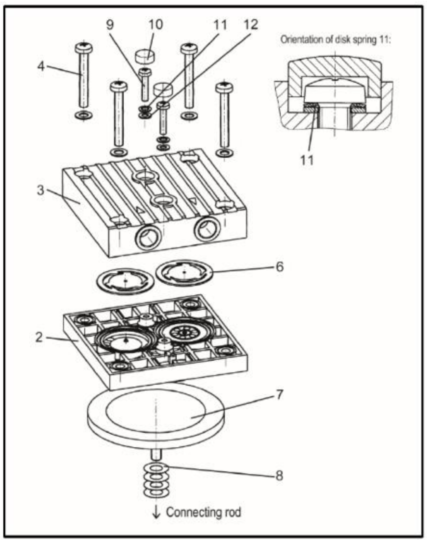
For more information on the maintenance of the air pump go N838 technical file (KNF 121249-121517) in the KNF folder under Reference Docs. No information is available on the frequency of the maintenance, therefore the pumps must be closely watched, when strange noises, vibration, a lack of flow or visual damaged parts are observed during the annual maintenance, the diaphragm of the pump might need to be replaced.

SOP 2.18. To replace the diaphragm on the N838 pump

1. Demount the Pump from the sniffer case
    a. Put the sniffer upside down
    b. Disconnect the power supply to the pump
    c. Disconnect the air inlet and outlet.
    d. Unscrew the 4 bolts that attach the CO2 frame to the sniffer casing
    e. Use Allen key to loosen the bolts of the pump
    f. Remove the pump from the sniffer
2. Unscrew the 4 bolts on the pump head
3. Remove the pump head and sealing (NOTE: pay attention to the direction of the pump head before removing)
4. Inspect the pump head sealing, replace if necessary
5. The diaphragm is installed under the pump head
6. Bring the diaphragm to pump top dead end by turning the fan
7. Remove the diaphragm by taking the edges of the lip and turning clockwise
8. Remove spacers on diaphragm
9. Check for dirt and clean if required by using pressured air or microfiber cloth

10. install spacers on the diaphragm
11. Put the pump in the top dead end position
12. Install the diaphragm
13. Reinstall the pump head and (new or old) sealing (orientation!)
14. Reinstall the pump in the sniffer
15. Reattach the tubing, make sure to block the G 1/8 (ISO parallel thread) to not damage the pump head (plastic)
16. Reconnect the power connection
17. Check for leaks using the soap solution

A buffer is installed just before the inlet of the air pump , no information is available about the maintenance or inspection of this buffer (PVC tube of 10 cm diameter and ca. 15 cm long). Nevertheless it is advised to check for leaks during the annual checks.



Legend
1 Housing
2 Intermediate plate
3 Head plate
4 Screw
5 Cover
6 Valve plate/sealing
7 Structured diaphragm
8 Diaphragm spacer
9 Screw
10 Screw cap
11 Disk spring
12 Washer

Figure 98 Assembling of the pump head

Pump 3 is used for the NOx sensor, this pump is from the same manufacturer but from a different line. This pump is the only of the 3 that uses 110VAC and is therefore not connected to the EPS power supply.

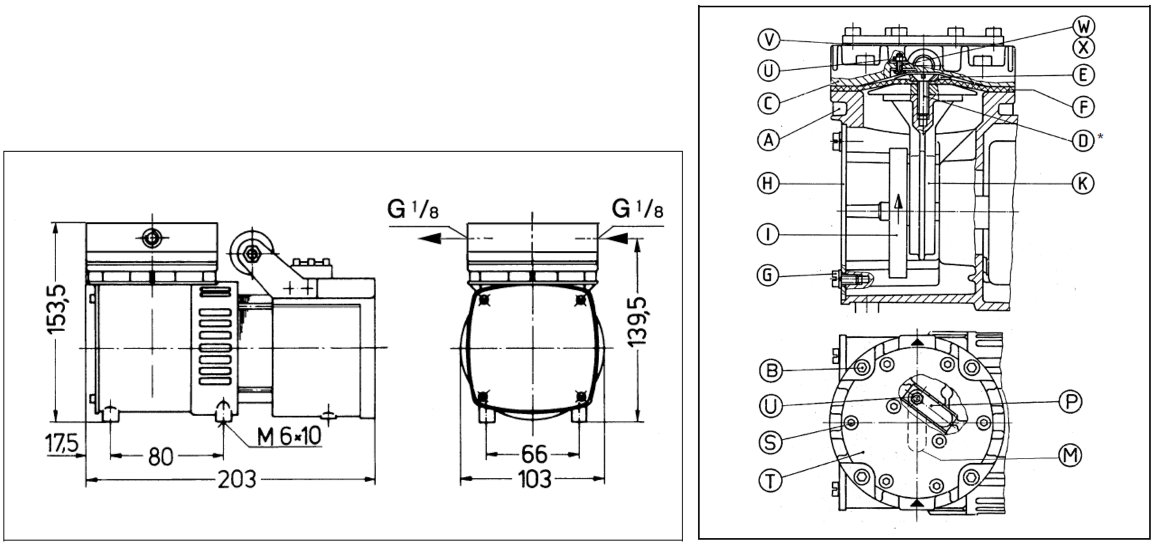


Figure 99 Diagram and parts of the N022 pump of the N022 pump

For more information on the maintenance of the air pump go N022 technical file (KNF 121226-121491) in the KNF folder under Reference Docs. As this sensor is producing ozone, the valves need to be replaced bi-annually. Nevertheless also this the pumps must be closely watched, when strange noises, vibration, a lack of flow or visual damaged parts are observed during the annual maintenance, the diaphragm of the pump might need to be replaced.

SOP 2.19. To replace the diaphragm on the N838 pump

1. Demount the Pump from the sniffer case
    a. Disconnect the power supply to the pump
    b. Disconnect the air inlet and outlet.
    c. Unscrew the bolts that attach the pump tray to the sniffer casing (Torx T40)
    d. Remove the pump tray from the sniffer
    e. Demount the pump from the pump tray
2. Mark the position of the pump head (C) with a pencil
3. Unscrew the 4 bolts on the pump head (Allen key 4)
4. Unscrew countersunk screw (D), remove retainer plate (E) and the diaphragm (F)
5. Remove screws (G) to remove cover plate (H)
6. Turn the counterweight so that the connection rod (K) is in the mid position, fit the new diaphragm, tighten the new countersunk screw (D) (5 Nm)
7. Change reed valves M and P
    a. Loosen the Allen screws S, remove the cover plate T and the gasket V
    b. Unscrew nut U, remove screw W, incl. washer X and reed valves P and M
    c. Fasten new reed valves P and M and fit new wash X and nut U
    d. Replace the cover plate with a new gasket V and tighten screws S
8. Reinstall the diaphragm head according to the marks
9. Tighten the bolts 5.5Nm

Figure 100 Example of damaged diaphragms

6.1.9 Internal tubing

A visual inspection can be executed during every opening of the sniffer sensor, not regular servicing is required for replacement. A leak test can be done together with the leak test of the external tubing during Hardware calibrations to look for damaged tubing or faulty fittings (see 6.4.2.)

6.1.10 Hydrocarbon kicker

No frequent regular maintenance is required for the hydrocarbon kicker. But due to wear or codding of the capillaries an annual leakage and flow test are recommended

SOP 2.20. To conduct a leak test on internal tubing

1. Remove hydrocarbon kicker from the sniffer casing
2. Add covers on the outer compartment and on the end
3. Connect to the synthetic air pressure cylinder
4. Add cover on the overflow valve
5. Add pressure of 1 bar
6. Spray soap liquid on tubing
7. Note the time to decrease to 0.5 bar (> 5min)
8. Remove covers from outer compartment and put them on the inner compartment
9. Repeat the steps 3-7 with the outer compartment

SOP 2.21. To test flow

1. Add covers on the inner compartment
2. Connect the inlet of the outer compartment to a fresh particle filter
3. Connect the outlet of the outer compartment to a flowmeter
4. Connect the outlet of the flowmeter to the Thomas pump
5. Use the 220-110V power converter to power the pump
6. Measure the flow, this should be min 5l/min

in case the flow is lower than 5l/min in the outer compartment, this is most likely due to clogging of one of the capillaries, the clogged capillary will need to be cleaned or replaced. On 5yr basis all capillaries should be disassembled and tested.

SOP 2.22. To clean a capillary

1. Disassemble different HC kickers
2. Remove the capillaries
3. Use isopropyl alcohol to clean the capillaries, use an air compressor or synthetic air to dry
4. Test the flow through each capillary
    a. Connect capillary to synthetic air cylinder,
    b. increase pressure to 2 bar and check if air flows through the capillary
    c. Not all capillaries have the same flow
    d. Capillaries with deviating flows should be replaced
5. Reassemble HC kickers
6. Reassemble Hydrocarbon kicker and reinstall it in the sniffer casing

6.1.11 Internal signal wiring

No maintenance is required for the wiring, if visually cable damage is observed this can only be replaced after identifying the wiring and consulting FluxSense. A standard Ethernet hub is used to connect all the Ethernet connectors to the MUMM_LOG_PC (MXU85A0001). These devices show generally no maintenance and are very reliable, in case of issues with Ethernet, the power supply and wiring can be inspected. If necessary the Ethernet hub can be replaced by an identical model.

6.1.12 Internal power distribution

In case of malfunctioning components the circuit-breakers must be checked first and if required be replaced. In case of component malfunctioning it is advised to read out the power from the power converters during general maintenance, they may be replaced if the current output is outside the limit (>20% difference).

6.1.13 Fans

Fans should be inspected during every opening of the sniffer sensor, they must be free from any blockage or contact with wiring, replace wiring if damaged. 2 types of fans are used, 3 x 80 mm fans (NMB) running on 115 V on the backside and 12 x 40 mm fans (Sunon) running on 5 V on the front side (installed in 3 blocks of 4 fans). Fans have low rate of failures and high life acceptancy (>20yr @ 100 flight days/year), in case the fans are no longer working, they must be replaced (available on RS or Mouser).

6.1.14 Sniffer casing

No regular maintenance is required for the casing. The screws may need to be replaced when the thread or head is damaged. Spare screws and bolts can be ordered via Styl Aviation.

After servicing and closing of the sniffer sensor, the convergence points between the top and bottom cover should be covered with aluminum tape (e.g. 3M 1436) to avoid EM interference in the cockpit.

6.2. Filters

Note: Optimally the changing of the filters can be combined with the hardware SO2 calibrations

Two fine particle filters are installed in the sniffer system, these filters can become kludged by time. No roll-over time is specified to change the filters, to enable a proper functioning of the sniffer system during intensive campaigns in busy shipping areas it is advised to change the filters on a two-annual basis as a precautionary measure, or when a decrease in flow is observed. The specifications of the filters are:

- Manufacturer: PAL
- Type: ACRO 4003 PTFE
- Size: 50
- Pore size: 1µm
- Connection: Threaded (with Teflon tape)

Filters can be ordered at VWR (customer nr: 41005569).

SOP 2.23. To replace the filters

1. Disassemble tubing to and from the filter box, close the open ends with covers
2. Remove the filter box (Velcro)
3. Open the box using a Philips screwdriver (PH1)
4. Unscrew the 1/4 Swagelok (tube fitting) using a wrench 7/16 (4x)
5. Remove the filters from the filter box
6. Unscrew the Swagelok-1/4"NPT female adapter on the filter
7. Check the adapter for left over Teflon tape
8. Put Teflon tape (5 turns) in clockwise direction on the new filter thread and reconnect the Swagelok adapters (4x) use modest force to tighten the adapters
9. Check if Teflon tape does not block the airflow
10. Reinstall the Filters by tightening the Swagelok tube fittings
11. Reinstall the filterbox and attach the tubing, leave the cover of the box open
12. Perform a leakage test, while the sniffer is powered on and taking in air, blow respiratory air on the filter connections, if no CO_2 is measured (IGPS or GHG), the filters are properly installed.
13. Close the box cover.

6.3. Client station PC maintenance and updates

Once a year all emission files should be copied from the IGPS folder and stored on the SURV FREENAS, also available under Seafile, 25-Sensor-Data/Sniffer-Data. If new AIS present or other IGPS software comes available this should be stored under 5-Instrument/FluxSense-Sniffer/Software afterwards the program files can be copied to the IGPS folder. All users should check the proper and full functionality of a new software version before the software can be installed on the MUMM-LOG-PC.

6.4. External Tubing

6.4.1 Assembling Swagelok connections

For assembling of flexible and stainless steel tubing, slightly turn Swagelok connector with back and front ferrules on fitting. Fully Insert the tube into the fitting, rotate the nut finger tight, mark nut at 6 o'clock position, and tightened further 1 and a quarter until the 9 o'clock position using wrenches.

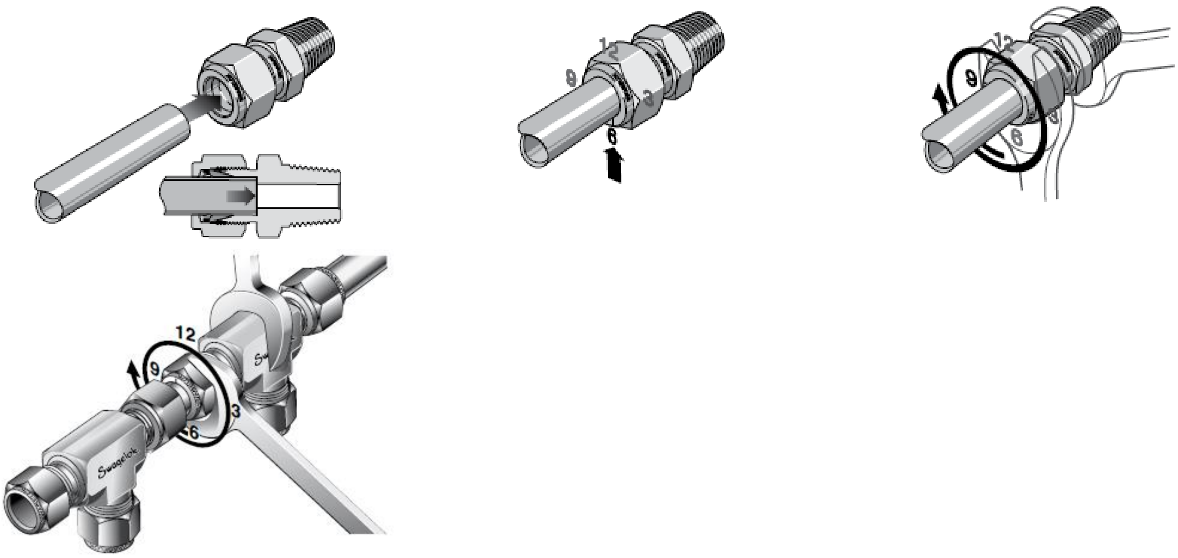


Figure 101 Assembly of Swagelok connections, (Swagelok, 2016)

To connect two male Swagelok connectors port connectors or reducers are used. To assemble adapters (e.g port connector see figure …) that come equipped with a machine ferrule end: discard the front and back ferrules and tighten 1 quarter.

Figure 102 Port connector with machine ferrule

Swagelok tube fitting can be disassembled and reassembled many times. Before disassembling mark the connector and tube, when reassembling, tighten until the mark, and further tighten slightly (1/6 of a turn) with a wrench.

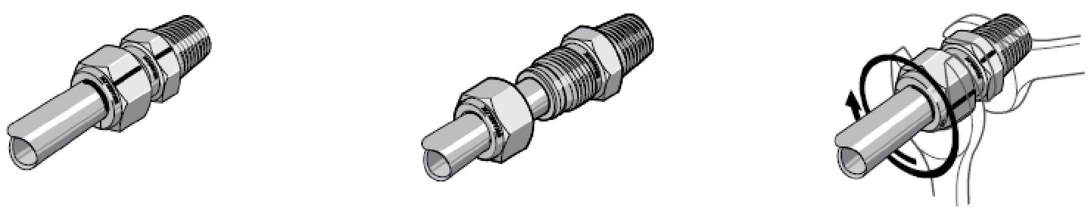


Figure 103 When reassembling, mark the connector prior to disassembling tighten until the mark and tighten slightly (1/6 is a good indication) with a wrench

6.4.2 Flexible tubing and fittings

The flexible tubing between the pitot tube and the sniffer, between sniffer and NOx sensor and between the regulator to the pitot tube should be checked for obstructions and/or leaks. Obstruction can be checked visually or when limited flow is observed. Checking for leaks can be done using a soap solution to check for overpressure leaks and by blowing on the connections to check for under pressure leaks (to be done by 2 persons):

SOP 2.24. To conduct leak test on flexible external tubing

1. When:
   a. **Tubing:** during the 6-monthly Thermo hardware calibration
   b. **Regulators (connections between the gas cylinder and the flexible hosing):** after every removal of the regulator from the cylinder (i.e. during calibration of the reference gasses)
2. Equipment:
   a. Soap solution
   b. Teflon tape (if necessary)
   c. Wrenches (7/16, 9/16, adjustable spanner)
3. Methodology
   a. Connect a CO_2 reference gas to the sample tube
   b. Make sure the reference gas cylinder valve is open
   c. Check if there is a positive outflow of the rotameter

- **d.** Spray soap solution on all the connections
- **e.** If no bubbles appear, there are no leaks
- **f.** Close the reference gas cylinder valve
- **g.** Check if overflow is zero
- **h.** One person blows on all the connections
- **i.** Second persons monitors the CO2 reading and watches for any abrupt change in the CO2 concentration
- **j.** In case no abrupt changes are observed, there are no leaks

In case leaks where observed, the malfunctioning connection should be sealed properly by using Teflon tape. In case a leak is observed in the flexible tubing the tubing should be replaced completely. In case a leak is observed or with a connection in the flexible tubing, the fle

6.4.3 Pitot tube

The Pitot tube can get contaminated with residues which results in absorption of SO2 in the airflow. To ensure the measurement quality, a contamination check needs to be executed on regular intervals and if necessary the Pitot tube should be cleaned with methanol or replaced with a new tube.

SOP 2.25. Cleaning pitot tube

1. When:
   - **a. Contamination test:** during HW calibrations (6 months)
   - **b. Cleaning:** when contamination test is positive
   - **c.** Preventive Replacement: Once every 24 months
2. Equipment:
   - **a.** Pipe cutter
   - **b.** Methanol (or iso propyl alcohol)
   - **c.** Stainless steel tubing (SS-T6-S-065-20)
   - **d.** Soap solution
   - **e.** Teflon tape (if necessary)
   - **f.** Wrenches (7/16, …, Adjustable spanner)
3. Contamination test
   - **a.** Connect the SO2 reference gas strait to the sniffer using a standard 1/4” Swagelok connector on the flexible tubing (remove the 3/8” fitting)
   - **b.** Open IGPS>>SNF
   - **c.** Open the SO2 gas cylinder
   - **d.** Wait 30 seconds, write down SO2
   - **e.** Close the valve
   - **f.** Connect the hose to the pitot tube,
   - **g.** Open the gas cylinder,
   - **h.** Write down the SO2 reading at 30 seconds and 35 seconds,
   - **i.** If the concentration from the first measurement is not within the range between the readings at 30’th and 35’th, the pitot tube needs to be cleaned
4. Cleaning
   - **a.** Unscrew the 12 screws from the pitot tube attachment plate with a Philips screwdriver
   - **b.** Disconnect the flexible tubing by unscrewing the 1/4 Swagelok fitting (7/16)

- **c.** Use methanol to clean the tube, make sure to rinse properly with water and dry the Pitot tube before remounting the pitot tube attachment plate.
- **d.** Perform the same test after cleaning, in case the absorption is observed, repeat step 4 until the reading is within limits or replace pitot tube.

5. Preventive replacement

- **a.** Unscrew the 12 screws from the pitot tube attachment plate with a Philips screwdriver
- **b.** Disconnect the flexible tubing by unscrewing the 1/4 Swagelok fitting (7/16)
- **c.** Remove bulkhead connector from the fuselage plate
- **d.** Untighten the 3/8 connection of the bulkhead connector
- **e.** Use a Swagelok pipe cutter to cut new 10 cm section from the Swagelok stainless steel tubing stock
  - Place tub in cutter in appropriate position
  - Rotate cutter, adjust tension every 2 turns with 1/8 of a turn
  - Continue until pipe is cut completely
- **f.** A new fitting should be used when connecting a new section to the bulkhead connector.
- **g.** Place the fitting on the bulkhead connector loosely
- **h.** Enter the tube section in the fitting (to the end)
- **i.** Tighten finger tight
- **j.** Mark connector at 6’ocklock
- **k.** Tighten with wrenches 1 and a quarter turn to the 9’ocklock position (use inside nut of bulkhead connector to provide counterforce)
- **l.** Check for leaks before remounting the pitot plate to the aircraft
  - connecting the hose to the Pitot tube (leave the other end open),
  - when the sniffer is powered-on, blow respiratory air on the pitot tube and other connectors,
  - in case of leakage this shall be seen in the IGPS or GHG graphs (CO_2 peak).

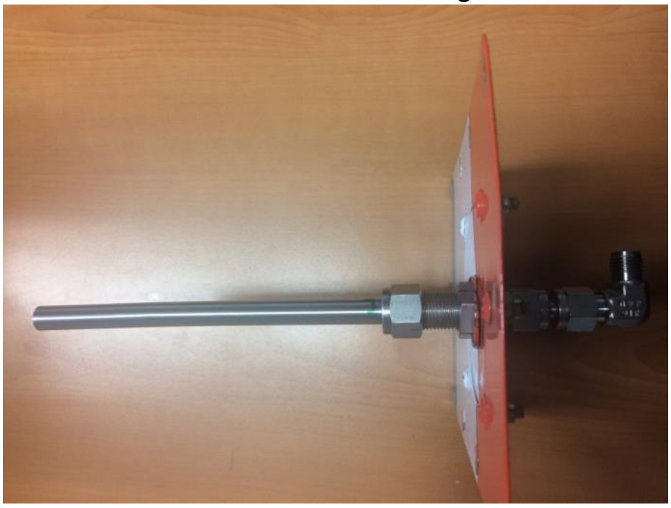


Figure 104 Pitot-Tube replacement (90° elbow is optionally)

Figure 105 Cutting a new section with Swagelok pipe cutter

6.4.4 Regulator

The connections (Swagelok of threaded Teflon connections) between the different parts of the regulator on the reference gas cylinders should be checked for leaks using a soap solution. In case a leak is observed, the malfunctioning connection should be first tightened slightly, when this does not close the leak, the connection should be disassembled and sealed properly by using Teflon tape.

SOP 2.26. Regulator inspection

1. **When**: after every removal of the regulator from the cylinder (i.e during calibration of the reference gasses)
2. Equipment:
    a. Soap solution
    b. Teflon tape (if necessary)
    c. Wrenches (7/16, …, Adjustable spanner)
3. Conduct a leak test
    a. After assembling regulator to the reference gas cylinder
    b. Open reference gas cylinder valve
    c. Check if there is a positive outflow of the rotameter
    d. Spray soap solution on all the connections
    e. If no bubbles appear, there are no leaks
4. To repair Threaded Teflon in case of leaks
    a. Disassemble connection
    b. Remove old Teflon from male side of the threaded connection
    c. Check for remaining Teflon tape in female side of threaded connection
    d. Hold new Teflon tap on male side of the threaded connection with finger
    e. Apply Teflon tape clockwise

6.5. External power distribution

The power distribution to and from the sniffer sensor should be visually inspected after every reinstallation of the sniffer sensor in the OO-MMM aircraft. Special attention should be made to avoid cable damages by using cable ties. An inspection may also be required in case of power issues. In case faulty wiring is observed, all defect wiring should be repaired by an authorized aircraft maintenance company (Part 145). An annual basis a battery capacity test (CAP) should be executed by the aircraft maintenance company on the emergency battery, if the capacity is less than 75% (7.5Ah) the battery units (Sonnenschein A512/10 S) should be replaced.

6.6. External signal wiring

All signal wiring between the sniffer sensor and the ASP connector panel should be visually inspected after every reinstallation of the sniffer sensor in the OO-MMM aircraft. Special attention should be made to avoid cable failure by using cable ties. An inspection may also be required in case of signal issues with Ethernet, AIS, GPS or Arinc. In case faulty wiring is observed, all wiring should be repaired by an authorized aircraft maintenance company (Part 145).

When the sniffer sensor wasn't used for a an extensive period, the IP configuration off the Thunderbolt dock connection might need to be reset on the client stations (see 7.7).

6.7. Sniffer rack

The screws and Teflon plates of the sniffer rack should be inspected during every disassembling of the sniffer sensor and need to be replaced when damage is observed. Styl Aviation can provide the screws, the Teflon plates can be provided by Airplus.

CHAPTER 7. TROUBLESHOOTING

7.1. Reset software calibration factors

The main issue to be expected is the observation of non-reliable reading during flight. In case the SO2 and CO2 concentrations in ambient are not stable or outside the normal range.

- SO2: between -5 to +5 ppb
- CO2: between 380 and 430 ppm
- NOx: between 0 and 20 ppb

Or when FSC measurements are not realistic (>5 or systematic <0), this is most likely due to a calibration issues or non-correct calibration procedures resulting in wrong calibration factors, e.g. by selecting the wrong concentration while doing a calibration or doing a calibration with a leaking or a contaminated tube, in case this problem occurred after a software calibration the software calibration factors can be reset in flight to the previous factors or cleared completely.

SOP 2.27. Resetting calibration factors

1. On MUMM_LOG_PC (via TeamViewer)
2. Close TCP log, if watchdog opens, close watchdog
3. Close IGPS present, if watchdog opens, close watchdog
4. Delete last Log file under IGPS>>TCP LOG (move to Sniffer Data>>LOGS)
5. Copy CALIBRATION.TXT file to QA_Follow up>>Backup>>cal
6. Open Calibration_Clean_up.exe, deselect the wrong calibration and save as CALIBRATION.TXT
7. If the previous calibration are not useful, calibration factors can be cleared completely, therefore delete the CALIBRATION.TXT file from the TCP LOG directory
8. Open Logger watchdog, TCP log will appear in few seconds
9. Open present watchdog, IGPS present will appear in few seconds
10. Go to IGPS present>>Utilities
11. In the left bottom corner the calibration factors are displayed, they can be reset by clicking "Clear Cal. Coef"
12. Calibration coefficients are now reset to 1 for the K-factor and 0 for the intercept
13. When clearing the Cal factors, make sure to check the last software calibration factors in SQMS_Follow_Up.xlsx, if the factors are more than 10% different from 1, a new software calibration is vital before any new measurements can be conducted.
14.

SOP 2.28. Replace SSD

1. In case the reset did not solve the issue, connect the reference gasses to the pitot tube and read out the concentration directly on the instrument (Licor: GHG, Thermo: Front-panel)
2. In case the readings are normal on the instrument but not on the IGPS, the issue is software related and must be solved by replacing the SSD of the MUMM_LOG_PC (7.5 Problems with the MUMM_LOG_PC).
3. If non-reliable measurements are observed on the instruments as well, there might be a problem with the pitot tube, the calibration gasses or the sensor components.

4. Check if the readings change when disconnecting the gas inlet and connect the reference gasses straight to the gas inlet on the sniffer, if the readings are now normal, the gas inlet needs to be inspected (see 6.4.3 Pitot tube).
5. If this did not solve the issue, the calibration gasses have to be inspected, this can be done by using a new cylinder, if the readings are normal with the new cylinder, the reference gasses need to be recalibrated
6. If also this did not solve the issue, the sensor components need to be inspected by using the troubleshooting procedures 7.2 to 7.4.

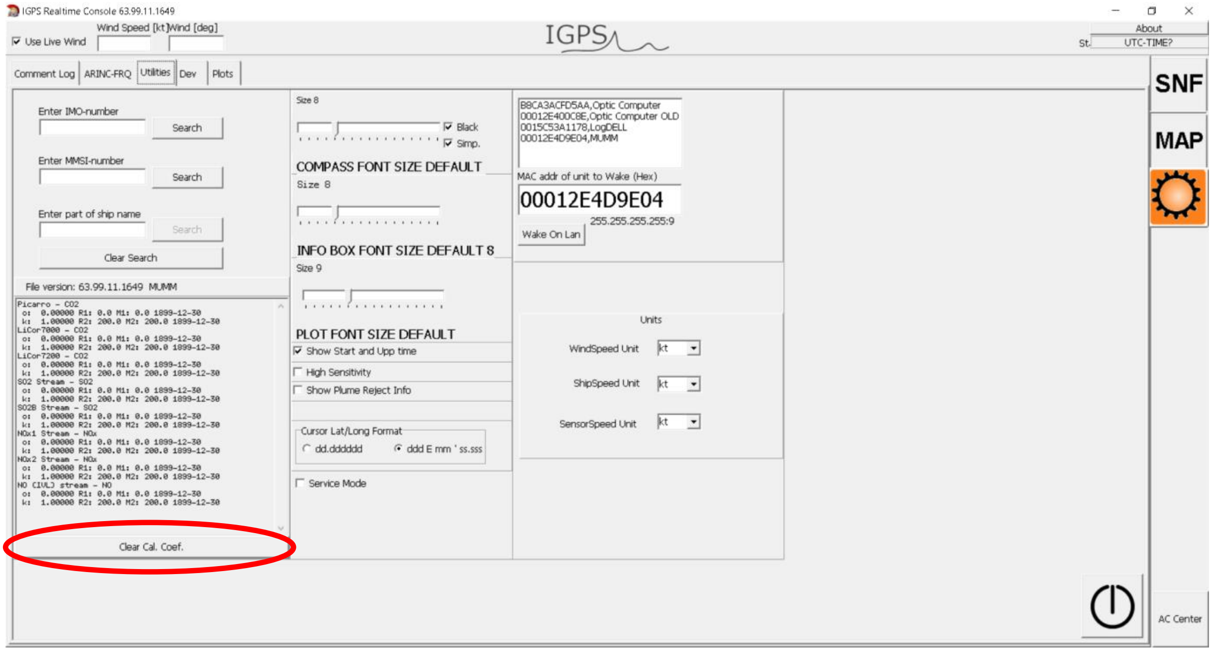


Figure 106 Utilities window of the IGPS present software

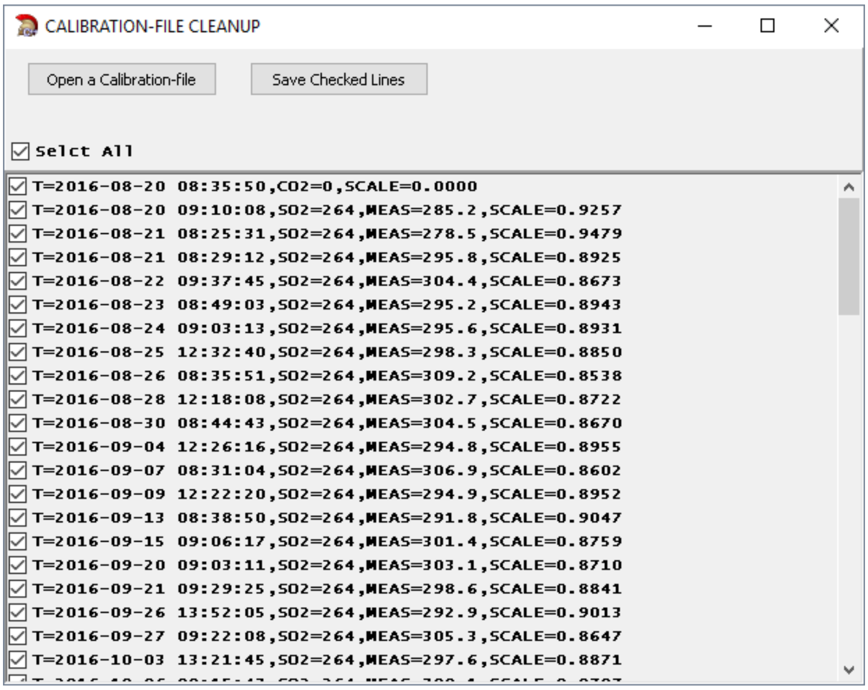


Figure 107 Calibration clean up tool

7.2. CO2 issues

If the data output of the Licor is not realistic and a calibration did not solve the problem or the data-output is not stable, for instance after software or maintenance update, follow the following procedure.

SOP 2.29. CO2 troubleshooting

1. Check data-output on the GHG software
2. If data is similar on the GHG software as on the AIS present, perform hardware calibration (see 4.1 L)
3. If data is different on the GHG software as on the AIS present, check the output settings
    a. Open GHG, select connect (via Ethernet) to 192.168.1.9
    b. Go to Licor>7200 output
    c. Check Setup tab (Delay should be 0 and Bandwidth should be 1 or 5) (see Figure 108)
    d. Check Ethernet tab (update rate should be 1-5, Data labels should be activated, Line feed should be selected, and all data labels should be selected)
    e. The other tabs or not important and can be neglected
    f. Select disconnect to activate changes
4. In case the previous step did not help, compare the current configuration with an old configuration file
    a. Open GHG, select connect (via Ethernet) to 192.168.1.9
    b. Go to "Config Files"
    c. Select "save configuration file"
    d. Save current configuration to QMS>>QA_Follow-up>>Backup>>Licor
    e. Open Excel file "comparison config files.xls"
    f. Go to Sheet "Import Config files"
    g. Select Data>>Get external data from TXT
    h. Select current config file (use all file types to see the config files)
    i. Use delimited, select "(" as delimiter and select finish
    j. Select the complete row and remove all other ")" characters
    k. Copy the row and paste the row in first sheet using "Paste special>>Transpose"
    l. Repeat steps f-l with a previous config file
    m. The files can be compared row by row with the previous configuration file using the excel file
5. If the configuration file is not similar in number of rows or in non-numeric data (YES/NO), upload a previous config file
    a. On GHG software, go to "Config Files"
    b. Select "Open configuration"
    c. Select the previous configuration file from QMS>>QA_Folluw-up>>Backup>>Licor
    d. Pop-up window will appear that configuration was loaded
    e. Select disconnect
    f. The sensor is no longer calibrated and a hardware calibration is required
6. In case the previous step did not solve the issue, data output from Ethernet can be checked with Realterm software
    a. Open Realterm software on MUMM_LOG_PC (see Figure 114)
    b. Go to Port, use port: 192.168.1.95:7200

   - **c.** Select “Change”
   - **d.** Go to Capture, select output folder and select “Start overwrite”
   - **e.** Compare the data string of the output with the data string from TCP log files (look for the data strings corresponding to the Licor sensor)
7. If the data strings are not similar and the settings cannot be changed using the GHG software (via Ethernet or Serial RS232), an embedded software reset might be required
   - **a.** Open the folder QMS\QA_Follow-up\Backup\Licor\downgrade\LI7200_embedded-8.0.0
   - **b.** Select Update7x00.exe
   - **c.** In case firewall opens, choose: ”allow access”
   - **d.** Select the instrument (191.168.95 port 7200)
   - **e.** Click start
   - **f.** Do not disconnect from the network during the process!
8. In case this did not solve the issue either, the sensor needs to be shipped to Catec for inspection

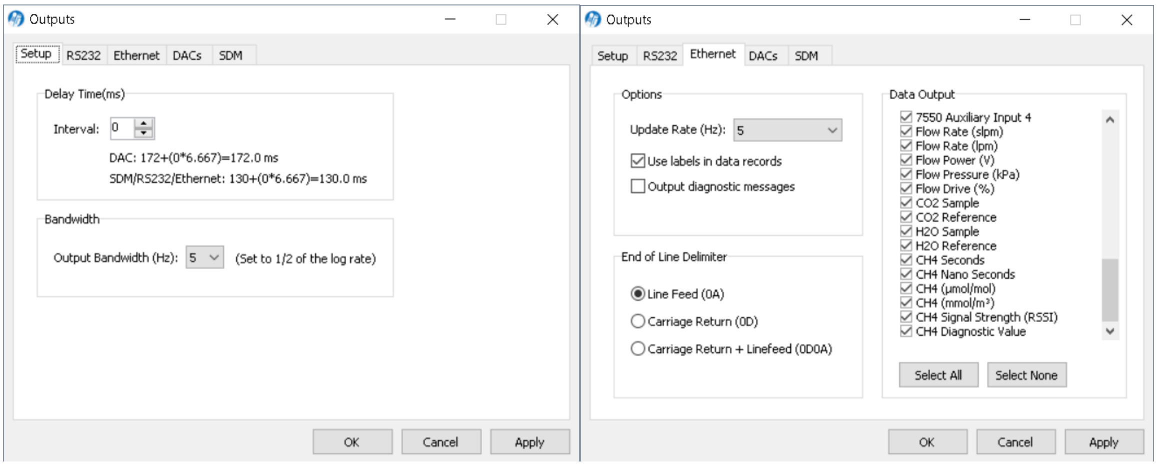


Figure 108 Output settings of Licor

Note that in case the uploading of configuration files and/or read out of the data on Realterm via Ethernet is not working, a serial connection can be used instead. A RS232 serial cable (Licor Turck serial cable 392-10268) can be installed in the sniffer sensor and connected to the MUMM_LOG_PC via the Licor Serial Converter (see image 62), this serial cable is equipped with a circular female 8-pin connector and DB9 female RS232 connector. The circular connector is connected to the connector panel, to use this serial connector an additional ribbon cable needs to be installed between the connector panel and the Licor 7550 unit (Harwin M50-9112042). The procedure for changing the settings or reading out the data is similar to the Ethernet connection with the difference that in this case the connection to the sensor with the GHG software is done via the Serial tab (after launching of the GHG sensor), the COM port can be identified in the Windows Device Manager (when connected a new COM port will be displayed). The same COM port can be used to read out the data with the Real term software (note that standard not all data labels are selected for the Serial output).

Figure 109 Connection to the LICOR sensor using serial cable

7.3. SO2 issues

In case the SO2 gives unreliable or non-stable readings. Diagnostics should be checked. Follow the maintenance procedures described under 6.1.2 THERMO 43i TLE. In case the diagnostics show a faulty component or bad parameter, Fabricom or FluxSense can be contacted to solve the issue. In case no problems are observed with the diagnostics and the readings (SO2 and Background) are normal with reference gasses, the problem is software related, to solve the issue the SSD of the MUMM_LOG_PC can be changed (see 6.1.5 MUMM_LOG_PC), make sure to back up the IGPS folder before doing this exchange to provide detailed information about the issue to FluxSense.

7.4. Airflow or pressure issues

In case the airflow is below the 5l/min (to be observed during the calibration), there might be a problem with either the Bronkhorst flowmeters, tubing or the KNF air pump.

SOP 2.30. Airflow trouble shooting

1. Check external tubing, connect Gas cylinder straight to the gas inlet on the sniffer
2. If normal airflow is observed, an obstruction is likely present in the tubing to the pitot-tube
3. In case this is not the case open sniffer (see 6.1 Internal sniffer sensor components)
4. Check visual all internal tubing for obstructions or leaks (see leak test in 6.4 External Tubing)
5. Replace the filters, even when they seem to be clean (see 6.2 F)
6. In case a visual inspection of the tubing and replacement of the filters did not solve the issue, check flow when connecting gas cylinder straight to the air pump (disconnect both in and outlet of the air pump, start with the output first). In case the same low flow rate is observed, the air pump needs to be inspected
7. In case a normal flow (10-30l/min) is observed the issue is not related to the air pump .
8. Check the Bronkhorst regulators using the FlowDDE and Flowplot software
   a. Open FlowDDE on MUMM_LOG_PC (see Figure 110)
   b. Open communication (COM4)
   c. Check Flow-Bus configuration
      - DFMFC (Flow Controller) should have 75% for Measure and Setpoint.
      - DEPC (Pressure Controller) should have 89% for Measure and Setpoint
   d. Make log file, compare parameters with previous log files, in case parameters are not normal, contact FluxSense to reset parameters or configuration
9. To view both pressure and flow
   a. Open Flowview
   b. Channel 1 will open (flow)
   c. Select advanced
   d. Open another window to view channel 2 (pressure)
   e. Check if pressure % is in line with setpoint
   f. When in flight an unstable pressure is observed (<150ft), lower pressure with 5-10%
   g. Check if flow is stable with new pressure
   h. Check if pressure is still within range for the Thermo sensor
   i. A full new hardware calibration is needed

Note: when Flowview is opened when FlowDDE is not running, an error is displayed and the Flowview need to be reset with the specific tool (on Desktop)

SOP 2.31. To monitor flow

1. In case parameters and configuration are normal check parameters with FlowView
   a. With FlowDDE running
   b. Open Flow View
   c. Check Channel 1 (Flow)
      - Open advanced settings
      - Check set (%)
   d. Check Channel 2 (Pressure)
      - Open advanced setting
      - Check set (%)
2. Use Flowplot to plot the evolution of the flow
   a. Connect Sniffer HDMI to HDMI display (Flowplot does not visualise in 640x480 view on VGA)
   b. Open Flowplot on MUMM_LOG_PC (see Figure 112)
   c. Compare plot with previous plots
3. In case the plots are not normal, the Bronkhorst regulators need to be calibrated (to be done by VMM)
4. In case the plots are normal or the calibration of the flowmeters did not solve the issue, an obstruction might be present in the Licor or Thermo sensor and need to be inspected. The Thermo sensor should be inspected by Fabricom first, before removing the Licor sensor and shipping the sensor to Catec.

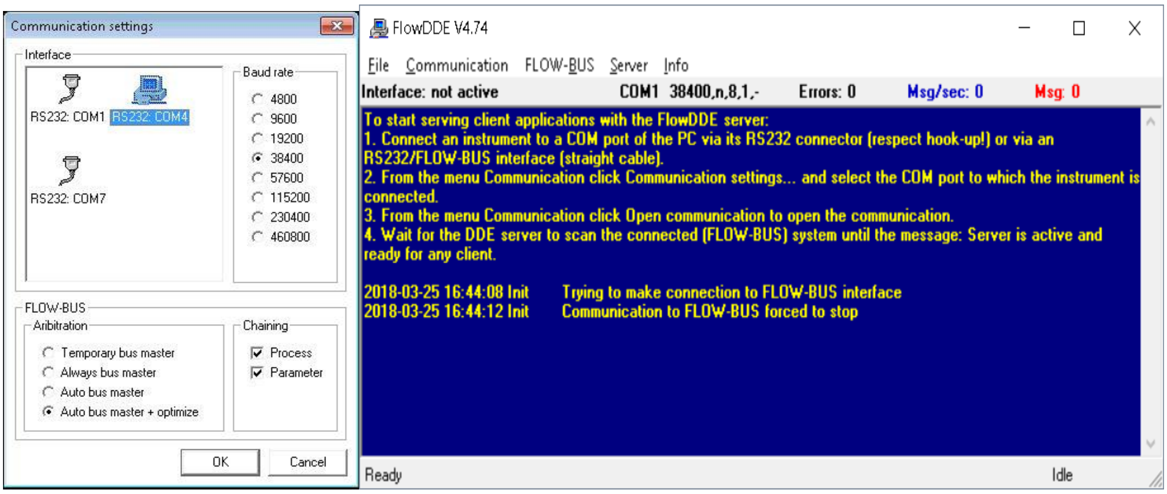


Figure 110 FlowDDE software

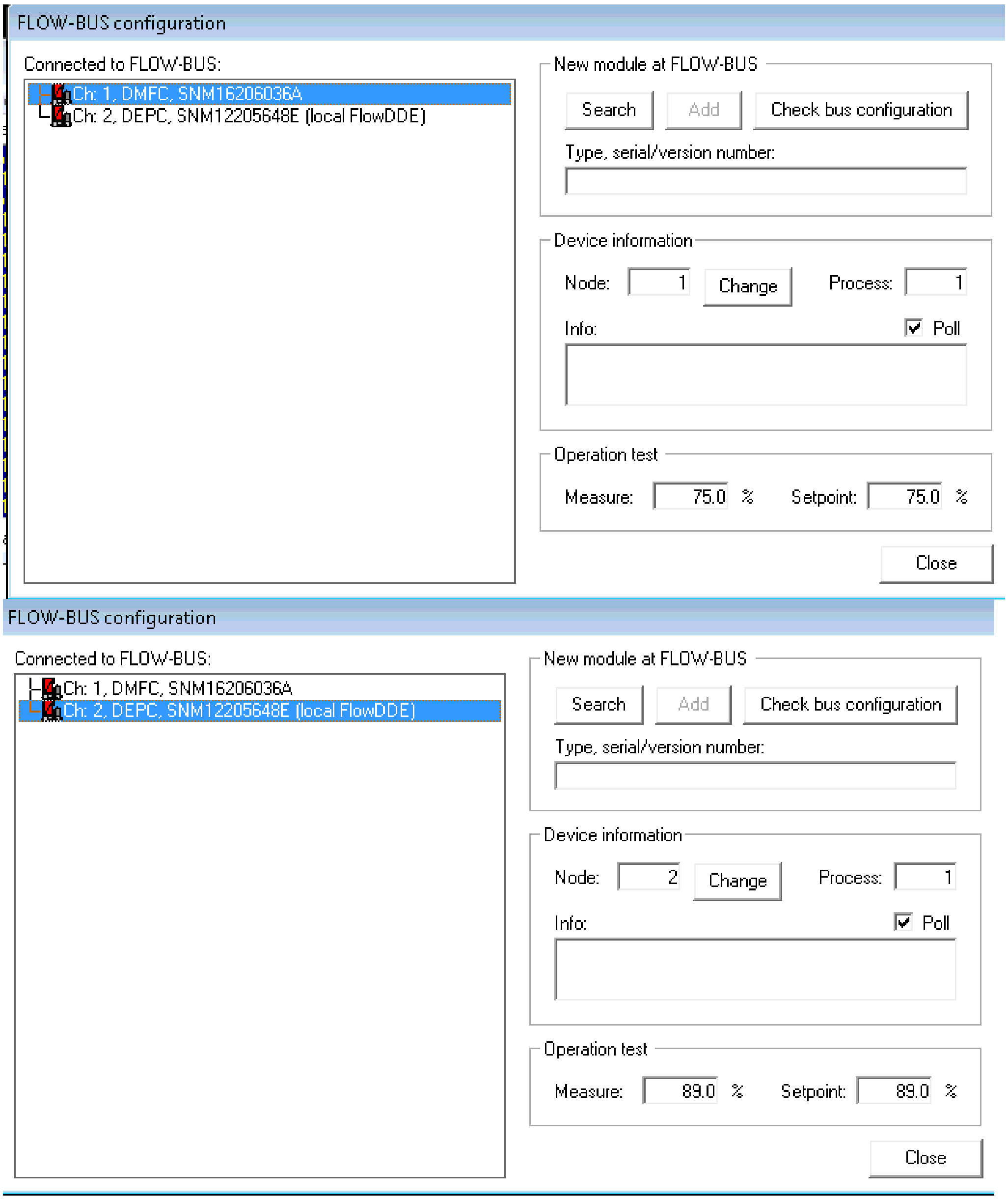


Figure 111 Flow Controller and Pressure controller configuration

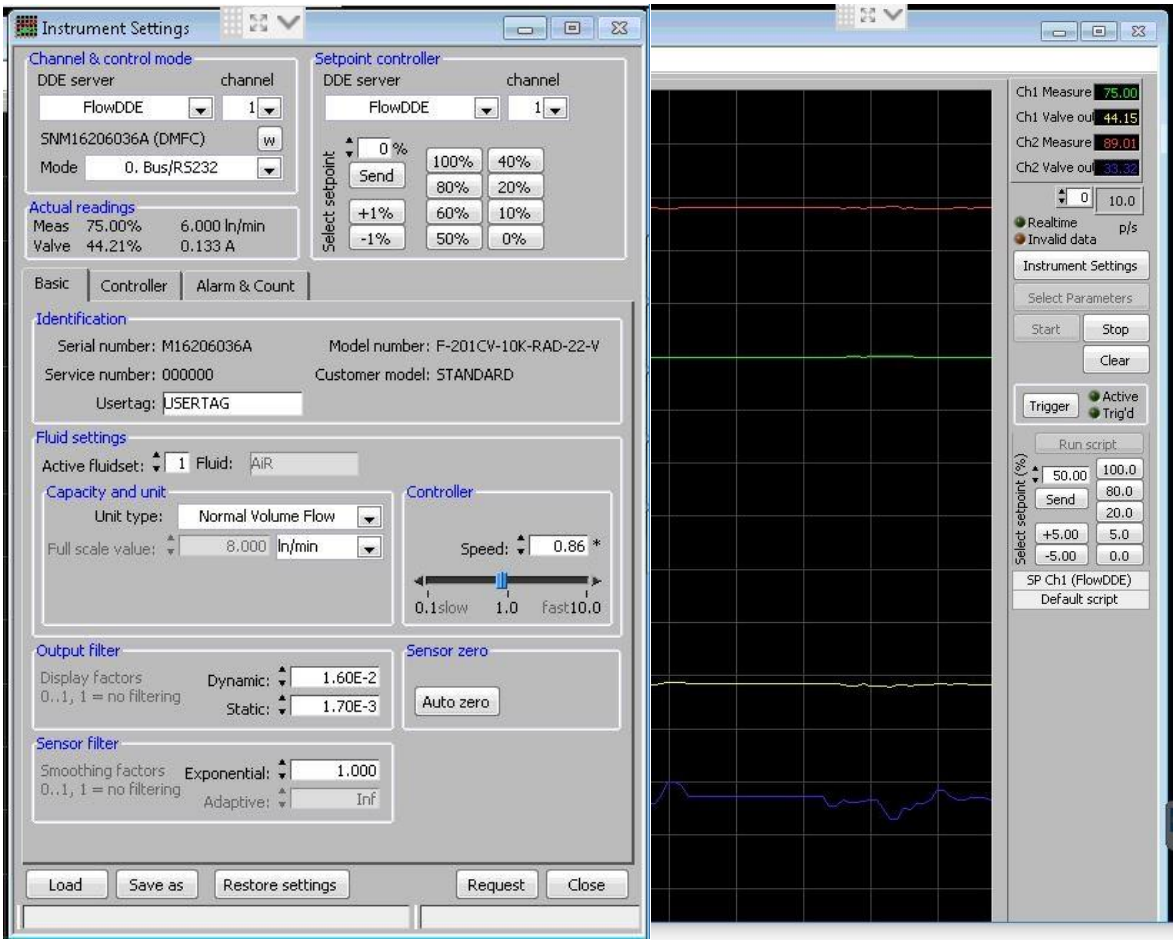


Figure 112 Flowplot

7.5. Problems with the MUMM_LOG_PC

In case the IGPS Present software does not open automatically on the MUMM_LOG_PC after booting, the sniffer needs to be installed in the aircraft with all cables and covers connected (especially the HDMI cable needs to be carefully inspected), the sniffer needs to be rebooted until the IGPS software starts again, several reboots might be required.

In case a MUMM_LOG_PC does not start automatically, check the Cockpit display to see the BIOS setup, connect Keyboard and mouse if necessary to the USB port. Reboot afterwards

If a drive problem or significant software issue is observed, the SSD can be replaced with the backup drive (see 6.1.5 MUMM_LOG_PC)

7.6. Problems with AIS+GPS receiver

SOP 2.32. Troubleshooting for AIS+GPS receiver

1. Check cabling to the ASP Connector panel
2. In case of AIS issues, it is advised to test one of the other 2 VHF antennas
3. In case of GPS issues or in case no AIS data is received with neither of the antennas, inspect data output
    a. Open Realterm on MUMM_LOG_PC
    b. Go to Port

   c. Select port 192.168.1.110:10001
   d. Select "Change"
4. In case data is received on the Realterm window but not on the AIS present, the issue is software related and can be solved by replacing the Hard drives of the MUMM_LOG_PC (see 6.1.5 MUMM_LOG_PC and 7.5 Problems with the MUMM_LOG_PC)
5. In case no data is observed, Open Sniffer (see 6.1 Internal sniffer sensor components) and check wiring (power and signal) visually, replace damaged wiring (to be done by FluxSense)
6. If no cable problems are observed, connect external Ethernet cable straight from the receiver to an external PC
7. Repeat step 3 with Realterm on external PC
8. In case data is received on the external PC, the Ethernet hub or Ethernet wiring might be malfunctioning and should be inspected further or replaced completely
9. In case no data is observed on the external PC either, replace the SLR200NG unit
10. If GPS problem is persistent, replace GPS antenna (to be done by ASP)

7.7. Problem with Thunderbolt dock

The Thunderbolt dock is connected to the sniffer using ethernet. When the laptop is not able to connect to the sniffer using the Thunderbolt do following steps:

SOP 2.33. Troubleshooting docking station

1. Is the laptop still charging?
2. If yes than the connection might be in the Ethernet settings of you Thunderbolt connection
   a. Go to network settings
   b. Go to Change adapter options
   c. Go to Ethernet x (the connection of your Thunderbolt)
   d. In case this is not present check the cabling (see step b)
   e. In case present,
      - go to settings (in admin mode)
      - Select Internet Protocol 4 (TXP/IPv4)
      - Check if your IP address is correct
3. If no, this means either the Thunderbolt is no powered or the cable is not plugged in in the docking station
   a. Open the front panel of the console
   b. Check cable connection to the docking station

7.8. Problem with Arinc info

In case no wind information is available for the IGPS software, the plumes will all be observed in the wake of the vessel. If this is observed in flight, the best thing to do is to manually add the wind information (from Medusa) in the IGPS software (in this case, the "use live wind" information check box, must be unchecked from all clients and the MUMM_LOG_PC). The issue can be checked after flight.

SOP 2.34. Troubleshooting ARINC

1. After full shutdown: disconnect the Arinc connecter and reconnect the connector on both the sniffer as the ASP connector panel (ASP-CON-6) (use pressure)

2. Reboot the system and avionics
3. During the next flight: check if data is available in ARINC-Freq tab under settings of the IGPS software and on the MEDUSA system on the console during flight or with all avionics enabled
4. If no data available on the MEDUSA system, the issue is related to the avionics or wiring, and has to be solved by ASP
5. If no data is available on the AIS present but on the MEDUSA system, check wiring from ASP-CON-06 to J251
6. If cabling is correct, use Realterm to check if data is available
    a. Open Realterm on MUMM_LOG_PC
    b. Go to Port
    c. Select port 192.168.1.121:9760
    d. Select “Change”
7. In case not data is available
8. Demount sniffer, turn sniffer upside-down and open Sniffer cover (see 6.1 Internal sniffer sensor components)
9. Reconnect all cabling and switch on avionics and sniffer
10. Check signal and power wiring and connections visually
11. Read out power to ARINC board
    a. Should be 24 Volt
    b. In case of power issue, replace the power converter (to be done by FluxSense)
12. Read out power to Ethernet converter (should be 5 volt)
    a. Should be 5 Volt
    b. In case of power issue, replace the power converter (to be done by FluxSense)
13. Inspect signal wiring
    a. Connect an external RS232 cable to a PC using a RS232 to USB converter and connect to the ARINC board
    b. Check in device management for the correct COM port (will appear after connecting the USB converter)
    c. Open Realterm, go to “Port”
    d. Select COM port and baud-rate
    e. Select “Change”
    f. Check for incoming data, this will appear in the main window
14. In case no data is observed or the data is scrambled, the ARINC board needs to be inspected or replaced (to be done by FluxSense)
15. In case the data is coming in normally, the issue can be software related or related to the signal cabling
16. Check the Ethernet cable:
    a. Reconnect the RS232 to Ethernet converter
    b. Replace the Ethernet cable from the RS232 converter with standard Ethernet cable to Ethernet port of the PC
    c. Open real term, go to “Port”
    d. Use the port 192.168.1.(port)
    e. Select “Change”
    f. Check for incoming data

17. If no data is received, the problem is related to the RS232 converter and should be replaced by FluxSense
18. If data is received, replace the Arinc Ethernet cable on the Ethernet hub by the external Ethernet cable
19. Reboot the sniffer sensor and check for incoming data using Realterm on the MUMM_LOG_PC and the AIS present software
20. In case data is received on the Realterm window but not on the AIS present, the issue is software related and can be solved by replacing the Hard drives of the MUMM_LOG_PC (see 6.1.5 MUMM_LOG_PC and 7.5 Problems with the MUMM_LOG_PC)
21. In case the data not received on the real term window and the AIS present, replace the Hard drive (see 18), if this does not solve the issue, it is most likely related to a hardware issue with the Ethernet hub, and the Ethernet hub should be replaced (to be done by FluxSense)

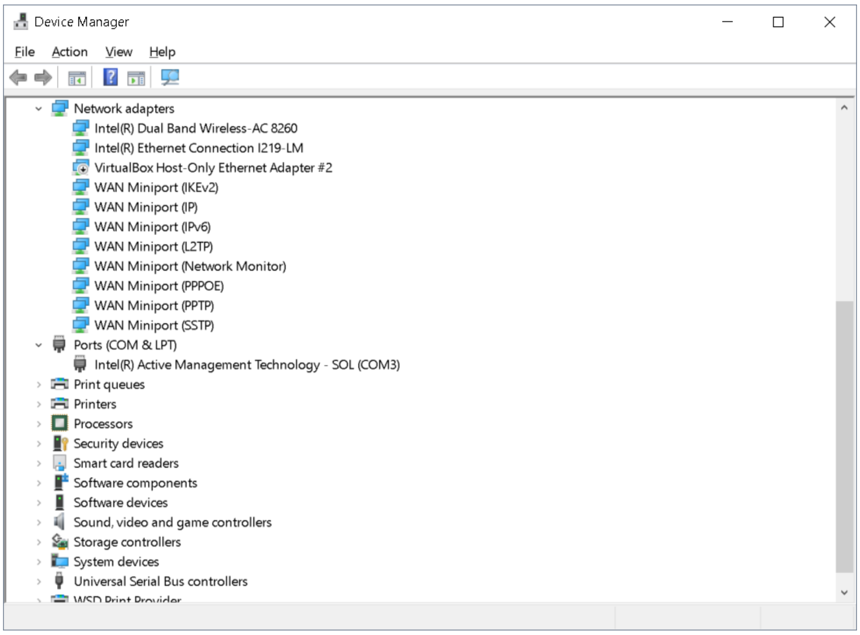


Figure 113 Device manager with COM ports

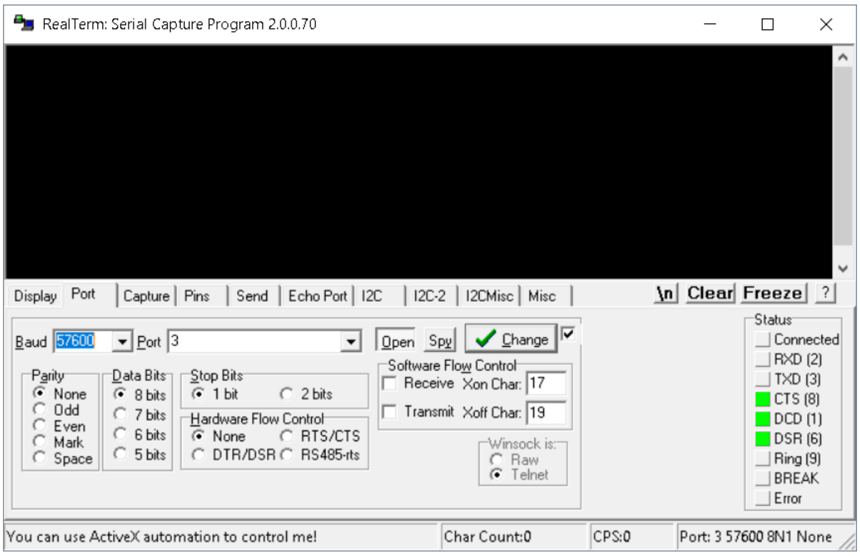


Figure 114 Realterm window

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https://www.rammount.com/part/RAM-VBD-128-SW1#

ANNEX A - PARTLIST

Table 11 Detailed partlist of internal component

PART	Model/Description	Manufacturer	Serial nr	Voltage	Amp (@28V)	Other specs
Thermo 43i TLE	SO2 sensor head AB9932	Fisher	THE-110838-00 (102311-03)	115 V	5.1 A (real: 1.25 A)	
	Power converter - Model LFWLT150-1003-K	Fisher	EQ1-D-Q227-1433			
	Front panel	Fisher				
	Ribbon cable		32200-000017-RS			
	Motherboard	Fisher				
	Measurement interface board					
	Lamp	Fisher				
	Photoconductor	Fisher				
	HV					
	Input board					
	Pressure sensor	Fisher	102272-03			
		Fisher	?-273-00			
		Fisher	?			
LICOR 7200RS	CO2 sensor U7211	Bioscience	72-1-0822	24 V	1.25 A (real:0.6 A)	
LICOR 7550	Controller	Bioscience				
	Ribbon cable	Bioscience	9972-056			
	Pressure regulator	Bioscience	PZ485			
	Serial cable	Bioscience (Trunck)	392-10268			
	Serial to USB	Bioscience	6400-27			
M50 Archer	Ribbon cable	Harwin	M50-9112042			
HBS 200-3-2,5	Regulator CO2	Airliquide		-	-	200 to 0.1-3 bar
HBSI 200-1-2	Regulator SO2	Airliquide		-	-	200 to 0.05-1 bar
Azote	Flow-meter	Dynaval		-	-	1-15 l/min
	Regulator CO2	Messer				
Rotameter	Overflow	Brooks	2510 A 2A13 S N VT	-	-	0-1 l/min
ARCO Filter	Filter	PAL	4003	-	-	PTFE 1µm, 50 mm

PART	Model/Description	Manufacturer	Serial nr	Voltage	Amp (@28V)	Other specs
T 1/4"	t-connection	Swagelok				
Fitting 1/4"	Ferrule connection SS: Steel,	Swagelok	SS-400-SET			
	NY Neylon		NY-400-SET			
Fitting 3/8"	Ferrule connection	Swagelok	SS-600-SET			
	SS: Steel		NY-600-SET			
	NY: Neylon					
Valve 1/4"		Swagelok				
Feed Through 3/8" to 1/4"	Female-female	Swagelok	SS-400-61-4 or SS-600-61-4			
Reducer 1/4" -3/8"	Female-female	Swagelok	SS-400-R-6			
Straight 1/4"	Male-Male	Swagelok	SS-T6-S-065-6ME			6m
3/8 tube	Steel tubing	Swagelok	SS-T6-S-065-6ME			
1/4 hose	Flexible tubing	Swagelok				
1/4" Straight union	Female-female	Swagelok	SS-400-6			
1/4" Togle valve	Female-female	Swagelok	SS-1GS4			
1/4" Union Elbow	Female-female	Swagelok	SS-400-9			
1/4" Union T-connection	Female-female	Swagelok	SS-400-3			
1/4" Bulkhead retainer	For feed through	Swagelok	SS-602-61F			
1/4" Nut ferrule SS	Nut for all 1/4" connectors	Swagelok	SS-400-SET			
3/8" Nut ferrule SS	Nut for all 3/8" connectors	Swagelok	SS-600-SET			
3/8" Nut ferrule NY	For removable connection to pito	Swagelok	NY-600-SET			
Buffer	Buffer	Chalmers				PVC tube, Diameter: 10cm length: 10 cm

PART	Model/Description	Manufacturer	Serial nr	Voltage	Amp (@28V)	Other specs
EL-FLOW F-201CV	Flow controler	Bronkhorst	M16206036A	24V	0.21 A (real: 0.2 A)	25ln/min 20ln/min 1000mbar
EL-PRESS P-502C F-004AC	Pressure regulator	Bronkhorst	M12205648E			
			M12205648C			
Inverter	SS120	KGS		28VAC-115VDC	1.10 A (real: 1)	Max 10.3 A output or 50A@28V 87% efficiency
5V Converter	Power converter (5 V)	Traco Power	TMP 15105C	100-240VAC to 5 VDC	Max 0.13 A (real: 0.05)	max 3 A output – 75% efficiency
12V Converter	Power converter (12 V)	Traco Power	TMP 30112C	100-240VAC to 12 VDC	Max 0.21 A (real: 0.03	max 2.5 A output - 79% efficiency
24V Converter	Power converter (24 V)	Traco Power	TMP 30124C	100-240VAC to 24 VDC	Max 0.21 A (real: 0.15 A)	max 1.25 A output - 79% efficiency
PM26726-838	N 838.1 KNDC-B	KNF	9315084	24VDC	2.4A (real: 1.4 A)	Pmax: 50 kPa (0.5 bar)
PJ44313-838.1.2	N 838.1-2 KNDC-B	KNF		24VDC	5A max (real 3.6A)	Pmax: 50 kPa (0.5 bar)
PM32615-N022	N022 ATE	KNF		110VAC	7.8A max (real 5A)	Pmax: 2.5 bar
ZMS100-24	Power converter (24 V)	TDK Lamda		24VDC	100Watt max 4.16A	
Ethernet hub (1)	Ethernet HUB		MXU85A0001	5V	0.17 A (real : 0.09 A)	
Serial to ethernet converter	RS232 to ethernet				0.17 A (real 0.06)	
Serial to USB converter	RS232 to USB			-	-	
SLR 200 NG	AIS/GPS Receiver	Comar	008-403	12V	0.17A (real: 0.05 A)	
Thunderbolt dock	Dock	Startech	TB3DK2DPPDUE	110V		
Thunderbolt cable	2m cable	Startech	TBLT3MM2MA			2m
Fans (large)	Fans (80mm)x3	NMB		115V	1:00 AM	9 W

PART	Model/Description	Manufacturer	Serial nr	Voltage	Amp (@28V)	Other specs
			3610PS-12T-B30-A00		(real: 0.85 A)	
Fans (small)	Fans (40mm)x8	Sunon	MF40060V1-000U-A99	5V	0.05 A (real: 0.04 A)	0.44W
Circuit breaker	Fuse 5A (x4)	Klixon		28V		
ZOTAC	Log PC	Zotac	Zbox Nano ID64	19 V	2 A (real: 0.7 A)	
Arinc Board	-	Olimex (Alta?)	-	12V	0.4A (real: 0.1 A)	
GPU	External power supply	Start Pac	53050	90-240VAC to 28.5VDC	0.2A (@220V)	Max 50A
External battery	2x internal 12V batteries	Sonnenschein	A52A /10S	12v		10Ah
Laptop	Client stations	Lenovo	T460s	20V	2.1A (real: 0.5 A)	
M3x10 T10	Sunken head SS screws casing					
M2.5x10 HEX 2.5	Allen SS screws on connectors					
M5 Locknut	Internal components and wiring					
M7 and M8 locknut	AIS+GPS and LOG_PC frame					
AIS antenna	FM Antenna	Cobham	CI 292-23			135-174 MHz
GPS antenna	LNA GPS receiver	Cobham	CI 401-220	12V	0.035A	
Sniffer power relay	T92 series	TE	T92P11D22-24			

ANNEX B - INTERFACE CONNECTION DOCUMENTATION

Table 12 Interface connection documentation

Connector design.	Signals			Pin	Signal	Connector		Cable type
						Equipment (chassis)	Cable	
J221 J233(4)	Ethernet	Pair Tx1	TX1+	1	Ethernet	RJFTV21G (Mfg. Amphenol)	RJFTV6MG (Mfg. Amphenol)	100 Ohm Shielded twisted pair & Shielded Cable. SPEC55 or ETFE
			TX1-	2				
		Pair Rx1	RX1+	3				
			RX1-	6				
J233(4)	115VAC			A	Pin size 20 115V AC 60 Hz (max 13 A)	D38999/ 20WB5SN (shell 11)	D38999/ 26WB5PN (Mfg. Amphenol, Souriau, other) + Back shell (Mfg. Glenair, other)	SPEC55 or other airframe wire (connections max7.5 A) AWG14 (10ft Max 70 A)
	115VAC return			B				
	DC 5V + Ethernet			C	5V (Ethernet hub)			
	DC 5V Return (DC 20 V + Docking station)			D				
	Chassis Ground (Chassis Ground, Return 5 and 20 V)			E				
J211	DC INPUT +28VDC			A	28V DC (max80 A)	MS3102E24-12P (shell 24)	MS3106E24-12S (Mfg. Amphenol, other)	SPEC55 or other airframe wire AWG12 (20ft max 26A)
	OUTPUT 115VAC			B	115V AC 60 Hz (max 23 A)			
	DC INPUT 28VDC RETURN			C	DC return			
	OUTPUT 115VAC Return			D	AC return			
	Remote ON/OFF (Connect to C for ON/ leave open for OFF)			E	DC (switch on flight deck)			
J231	Signal			Center	162 MHz AIS Antenna	N-Connector R191381000 (Mfg. RADIALL)	N-Connector Depends on cable	50 Ohm ETFE coax.
	Ground			Outer				
J241	Signal /+5V for LNA			Center	1.2-1.6 GHz GPS Antenna	N-Connector R191381000 (Mfg. RADIALL)	N-Connector Depends on cable	50 Ohm ETFE coax.
	Ground			Outer				
J251	ARINC A			A	100kHz ARINC 429	D38999/ 20WF32PN (shell size 19)	D38999/26WF32SN (Mfg. Amphenol , Souriau, other) + Back shell (Mfg. Glenair, other)	Shielded twisted pair. SPEC55 or other airframe wire (connections max7.5 A)
	ARINC B			B				
	Pin 1-2 (J1) Ground			C	Thermo panel remote connection Pin size 20 (max 5 A) max length 1m			
	Screen ARINC			D				
	Pin 3 (J1) LCLK			E				
	Pin 4-5 (J1) Ground			F				
	Pin 6 (J1) LLP			G				
	Pin 7 (J1) LFLM			H				
	Pin 8 (J1) LD4			J				
	Pin 9 (J1) LD0			K				
	Pin 10 (J1) LD5			L				
	Pin 11 (J1) LD1			M				
	Pin 12 (J1) LD6			N				
	Pin 13 (J1) LD2			P				
	Pin 14 (J1) LD7			R				

Connector design.	Signals	Pin	Signal	Connector		Cable type
				Equipment (chassis)	Cable	
	Pin 15 (J1) LD3	S				
	Pin 16 (J1) LCD Bias Voltage	T				
	Pin 17 (J1) +5V	U				
	Pin 18-19 (J1) Ground	W				
	Pin 20 (J1) LCD_ONOFF	X				
	Pin 21 (J1) Keypad Row 2 Input	Y				
	Pin 22 (J1) Keypad Row 1 Input	Z				
	Pin 23 (J1) Keypad Row 4 Input	a				
	Pin 24 (J1) Keypad Row 3 Input	b				
	Pin 25 (J1) Keypad Col 2 Input	c				
	Pin 26 (J1) Keypad Col 1 Input	d				
	Pin 27 (J1) Keypad Col 4 Input	e				
	Pin 28 (J1) Keypad Col 3 Input	f				
	Pin 29-32 (J1) Ground	g				
	Pin 33 (J1) +24 V	h				
	Pin 34 (J1) +24 V	j				
J261 Pumps PWR	28VDC Input	A	28V DC pin size 12 (Max 41A)	62GB12E1402PN (shell 14)	62GB16F1402SN (Shell 14)	AWG12 (6 ft Max 35 A)
	28VDC Return	B				
J271 USB	USB signal (5volt)	USB female	-	Switchraft EHUSBAABX	USB male (both sides)	Shielded USB
J281 HDMI	HDMI Signal	HDMI female	-	Switchraft EHHDMI2B	HDMI male (both sides)	Shielded HDMI
J291 Serial BC	RX	1	BC serial to ethernet converter	Serial male	Serial female	AWG20
	TX	2				
	-	3				
	-	4				
	Ground	5				
	-	6				
	-	7				
	5V input BC	8				
	5VDC Return BC	9				
J213 NOx power	115VAC	A	Pin size 20 115VAC (max 7.5 A)	D3899920WA98PN (shell size 9)	D3899926WA98SN Or TV06RW-9-98S (shell size 9) backshell M85049/38-9W	AWG16 (20ft max 40A)
	115VAC return	B				
	Ground not used	C				
Power input AC	DC INPUT +28VDC	A	28V DC pin size 12 (Max 41A)	62GB12E1402SN (shell 14)	62GB16F1402PN (shell 14)	SPEC55 or other airframe wire AWG12 (6 ft Max 35 A)
	DC INPUT 28VDC RETURN (ground)	B				

Connector design.	Signals	Pin	Signal	Connector		Cable type
				Equipment (chassis)	Cable	
Power input GPU	DC INPUT +28VDC	A	28V DC pin size 12 (Max 41A)	62GB12E1402PN (shell 14)	62GB16F1402SN (Shell 14)	SPEC55 or other airframe wire AWG12 (6 ft Max 35 A)
	DC INPUT 28VDC RETURN (ground)	B				
Power output	DC Output +28VDC	A	28V DC pin size 12 (Max 41A)	62GB12E1402SN (shell 14)	62GB16F1402PN (shell 14)	SPEC55 or other airframe wire AWG12 (6 ft Max 35 A)
	DC output 28VDC RETURN (ground)	B				
Battery to EPC	28VDC	A	28V DC pin size 16 (Max 22A)	62GB12E1203SN (Shell 12)	62GB16F1203PN (Shell 12)	SPEC55 or other airframe wire AWG12 (6 ft Max 35 A)
	Unused	B				
	28VDC return	C				
J311 EPC sniffer	28VDC input	A	28V DC pin size 16 (Max 22A)	62GB12E1203SN (Shell 12)	62GB16F1203PN (Shell 12)	SPEC55 or other airframe wire AWG12 (6 ft Max 35 A)
	28VDC output to Pumps	B				
	28VDC return (Ground)	C				
J411 Extern Ethernet hub (power)	DC Input +5V	A	Pin size 20 5VDC (max 7.5 A)	D3899920WA98PN (shell size 9)	D3899926WA98SN TV06RW-9-98S (shell size 9) backshell M85049/38-9W	AWG16 (20ft max 40A)
	(unused)	B				
	DC input Return (ground)	C				

Table 13 Wiring connections

	Connecting Units		Connects to			
Wire #	Unit1	Unit2	Term 1	Term 2	Type of signal	Nom Val
401	J211	Opto Coupler	4	Pin E		28V DC
402	Opto Coupler	Inverter	2	Pin E		28V DC
403	Opto Coupler	50 A Circuit breaker	1	N/A	Control	28V DC
404	50A fuse	Inverter	Pin 1	Pin A	External Power	28V DC
405	J211	50A Circuit breaker	Pin A	Pin 2	External Power	28V DC
406	J211	Inverter	Pin C	Pin C	External Power	GND 28V DC
407	Circuit breaker 1 5A	Inverter	Term 2	Pin B	AC Power	115V AC L
408	Circuit breaker 1 5A	J211	Term 1	Pin B	AC Power	115V AC L
410	Opto Coupler	Opto Coupler	Pin 1	Pin 3		28V DC
411	Circuit breaker 1	Circuit breaker 2	Term 2	Term 2	Power	115V AC L
412	Circuit breaker 2	Circuit breaker 3	Term 2	Term 2	Power	115V AC L
413	Circuit breaker 3	Circuit breaker 4	Term 2	Term 2	Power	115V AC L
414	TMP15105C	TMP30112C	AC	AC	Power	115V AC L
415	TMP15105C	TMP30112C	AC	AC	Power	115V AC N
416	TMP30124C	TMP15105C	AC	AC	Power	115V AC L
417	TMP30124C	TMP15105C	AC	AC	Power	115V AC N
418	Connector Power	Connector Block 1 Row1		422	Power	115V AC N
419	Connector Power	Connector Block 1 Row 3		421	Power	115V AC L
420	Circuit breaker 1	Connector Block 1 Row 3	Term 1		Power	115V AC L
421	TMP30124C	Connector A	AC	419	Power	115V AC L
422	TMP30124C	Connector A	AC	418	Power	115V AC N
423	Ethernet Switch	TMP15105C	+Vout	Term 1	Power	5V DC
424	Ethernet Switch	TMP15105C	-Vout	Term 2	Power	GND 5V DC
425	TMP15105C	Power Bridge	+Vout	431	Power	5V DC
426	TMP15105C	Power Bridge	-Vout	432	Power	GND 5V DC
427	TMP30112C	Power Bridge	+Vout	433	Power	12V DC
428	TMP30112C	Power Bridge	-Vout	434	Power	GND 12V DC
429	TMP30124C	Power Bridge	+Vout	435	Power	24V DC
430	TMP30124C	Power Bridge	-Vout	436	Power	GND 24V DC
431	Power Bridge	Connector D	425	Term 1	Power	5V DC
432	Power Bridge	Connector D	426	Term 2	Power	GND 5V DC
433	Power Bridge	Connector C	427	Term 1	Power	12V DC
434	Power Bridge	Connector C	428	Term 2	Power	GND 12V DC
435	Power Bridge	Connector B	429	Term 1	Power	24V DC
436	Power Bridge	Connector B	430	Term 2	Power	GND 24V DC
437	Connector D	Block 2 Row 2	431	Any	Power	5V DC
438	Connector D	Block 2 Row 1	432	Any	Power	GND 5V DC
439	Connector C	Block 2 Row 4	433	Any	Power	12V DC
440	Connector C	Block 2 Row 3	434	Any	Power	GND 12V DC
441	Connector B	Block 2 Row 6	435	Any	Power	24V DC

	Connecting Units		Connects to			
Wire #	Unit1	Unit2	Term 1	Term 2	Type of signal	Nom Val
442	Connector B	Block 2 Row 5	436	Any	Power	GND 24V DC
449	Olimex Card	Block 2 R3			Power 0V	GND 12V DC
450	Olimex Card	Block 2 R4			Power +12V	12V DC
451	EthernetToRS232	Block 2 Row 1			Power 0V	GND 5V DC
452	EthernetToRS232	Block2 Row 2			Power +5V	5V DC
453	Log computer PSU – L	Block 1 Row 4			AC – Power L	115V AC L
454	Log computer PSU – N	Block 1 Row 5			AC – Power N	115V AC N
455	19V PSU	Log computer			Power 0V	GND 19V DC
456	19V PSU	Log computer			Power +19V	19V DC
457	AIS	Block 2 Row 5			Power 0V	GND 12V DC
458	AIS	Block 2 Row 4			Power +12V	12V DC
477	Connector FAN	Connector Block 1 Row 5	N		Power	115V AC N
478	Connector FAN	Connector Block 1 Row 4	~		Power	115V AC L
479	J291	Connector Block 1 Row 1	B		Power	115V AC N
480	J291	Connector Block 1 Row 6	A		Power	115V AC L
482	J291	Connector Block 1 Row 6	E			GND
485	Licor	Connector Block 2 Row 6			Power	24V DC
486	Licor	Connector Block 2 Row 5			Power	GND 24V DC
502	EthernetToRS232	Bronkhorst	4	4	Gnd	GND
503	EthernetToRS232	Bronkhorst	3	1	RS232 TX	RS-232 type
504	EthernetToRS232	Bronkhorst	6	6	RS232 RX	RS-232 type
560	EthernetToRS232				Gnd	
601	40 mm fan	Fan 2 conn	Black			GND 5V DC
602	40 mm fan	Fan 2 conn	Red			5V DC
603	40 mm fan	Fan 2 conn	Black			GND 5V DC
604	40 mm fan	Fan 2 conn	Red			5V DC
611	Fan 2 conn	Block 2 Row 1				GND 5V DC
612	Fan 2 conn	Block 2 Row 2				5V DC
4771	80 mm fan	80 mm fan				115V AC N
4772	80 mm fan	80 mm fan				115V AC L
4781	80 mm fan	80 mm fan				115V AC N
4782	80 mm fan	80 mm fan				115V AC L

	Connecting Units		Connects to			
Wire #	Unit1	Unit2	Term 1	Term 2	Type of signal	Nom Val
4904	PSU	SO2 Pump	0V	VO-	Power 0V	
4905	PSU	SO2 Pump	+Vout	VO+	Power +	
4906	Bronkhorst	Block 2 Row 5			Power 0V	GND 24V DC
4907	Bronkhorst	Block 2 Row 6			Power +24V	24V DC
4908	SO2 Connector	Block 1 Row 2			AC N	115V AC N
4909	SO2 Connector	Circuit breaker 4			AC L	115V AC L
4910	SO2 Connector	Block 1 Row 6			GND	GND
4911	PJ2	SO2	2	3	Power N	115V AC N
4912	PJ2	SO2	1	1	Power L	115V AC L
4913	PJ2	SO2	3	5	Power GND	115V AC GND
49042	Pump PSU	Block 1 Row 5			Power	115 AC N
49052	Pump PSU	Block 1 Row 4			Power	115 AC L
409A	J211	Block 1 Row1	D			115V AC N
409B	Inverter	Block 1 Row1	B	N/A		115V AC N
A	Interface Board	J251		A		
B	Interface Board	J251		B		

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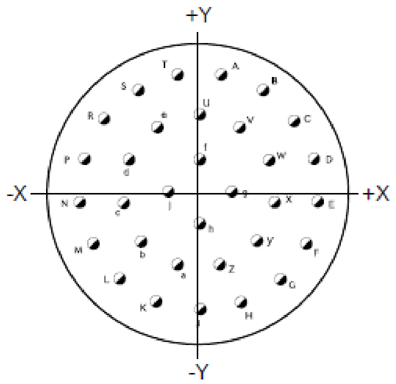


Ctc	X	Y	Ctc	X	Y
A	+1.68	+8.97	T	-1.68	+8.97
B	+4.80	+7.75	U	0.00	+5.84
C	+7.26	+5.51	V	+3.15	+4.90
D	+8.76	+2.49	W	+5.31	+2.41
E	+9.07	-0.84	X	+5.79	-0.84
F	+8.15	-4.06	Y	+4.42	-3.84
G	+6.15	-6.73	Z	+1.65	-5.61
H	+3.30	-8.51	a	-1.65	-5.61
J	0.00	-9.12	b	-4.42	-3.84
K	-3.30	-8.51	c	-5.79	-0.84
L	-6.15	-6.73	d	-5.31	+2.41
M	-8.15	-4.06	e	-3.15	+4.90
N	-9.07	-0.84	f	0.00	+2.44
P	-8.76	+2.49	g	+2.44	0.00
R	-7.26	+5.51	h	0.00	-2.44
S	-4.80	+7.75	j	-2.44	0.00

Figure 115 J251

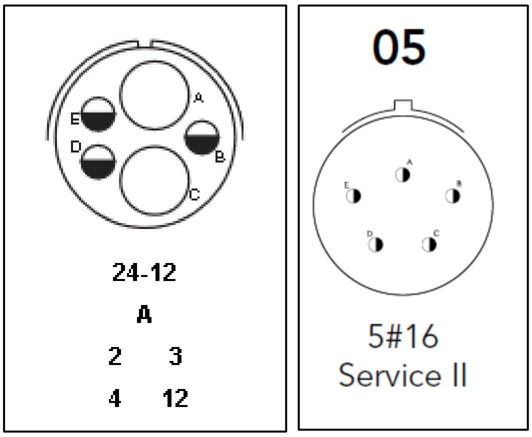


Figure 116 J211 (left) J233 right

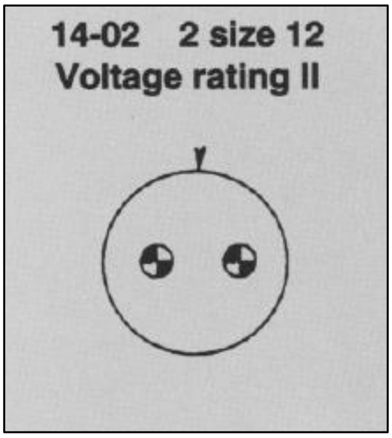


Figure 117 Connector on ASP-CON-06, GPU and external battery (Amphenol 62GB, size 14, 2 pins)

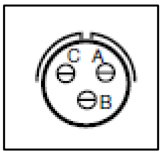


Figure 118 NOx Power connector (Amphenol 38999 series III, shell size 9, 3 pins)

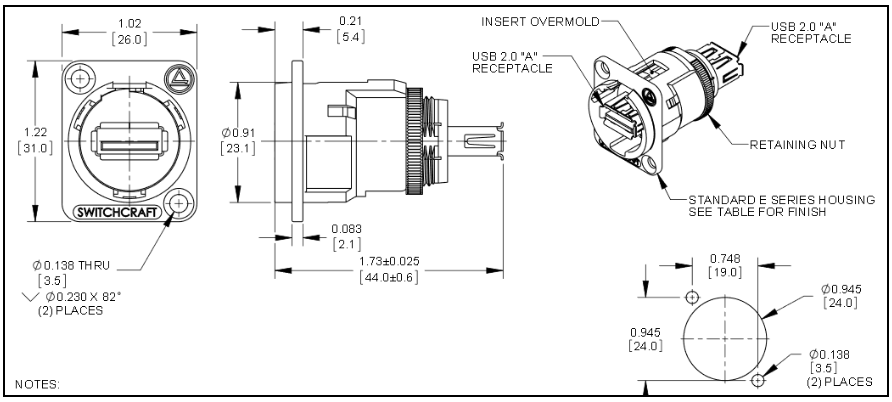


Figure 119 USB and HDMI connectors

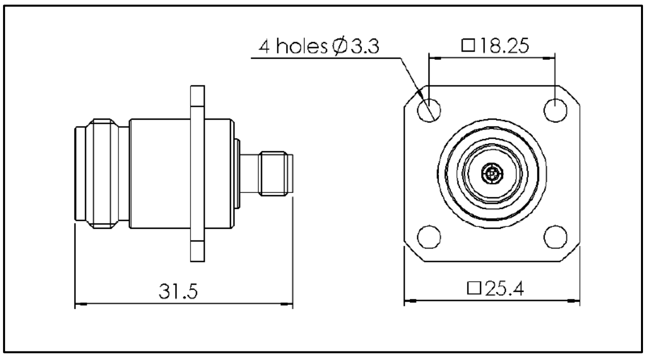


Figure 120 N-connector (RADIALL) used for AIS and GPS antennas (J231 and J241)

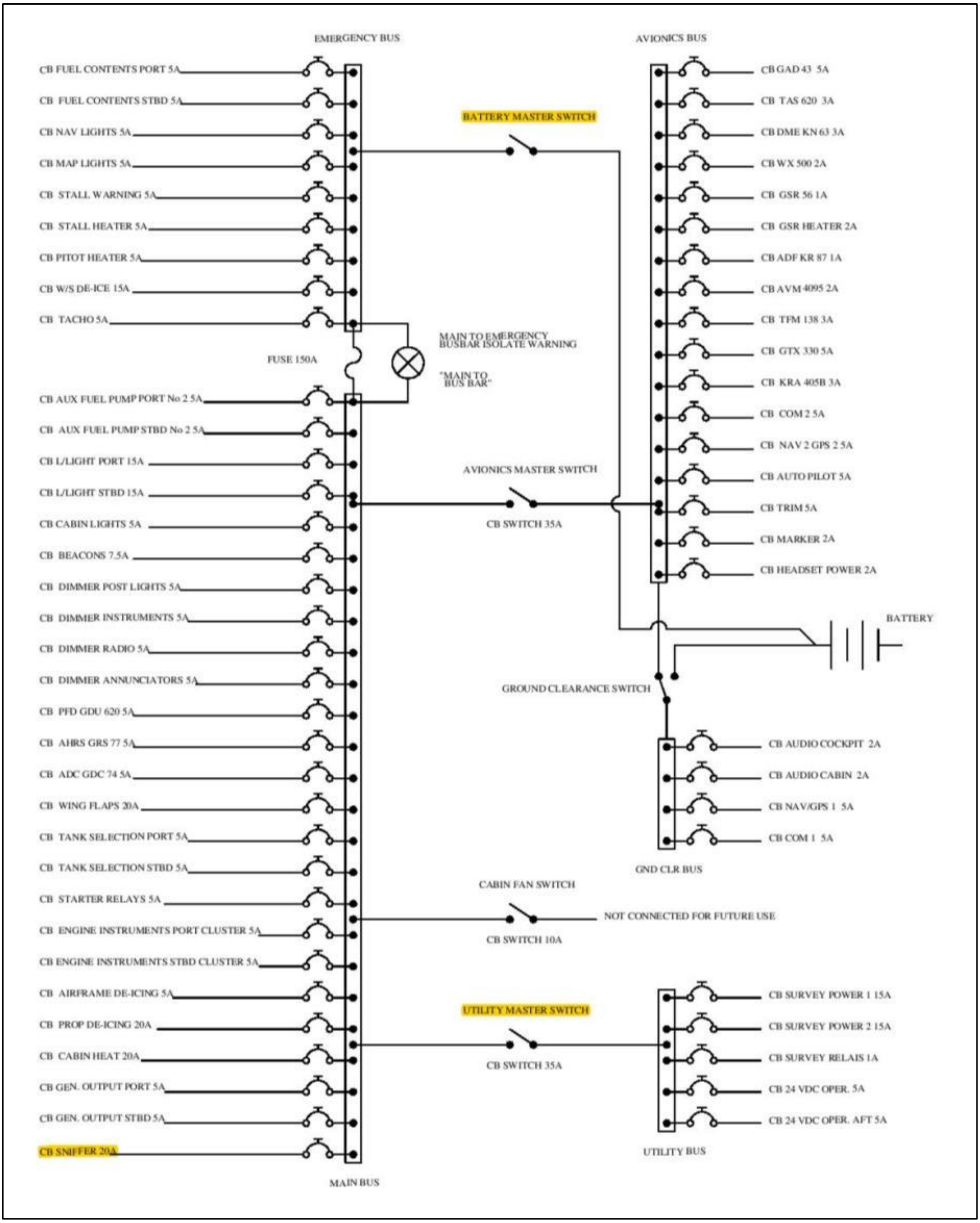


Figure 121 General aircraft power wiring diagrams with Sniffer circuit braker and Master Switch (marked)

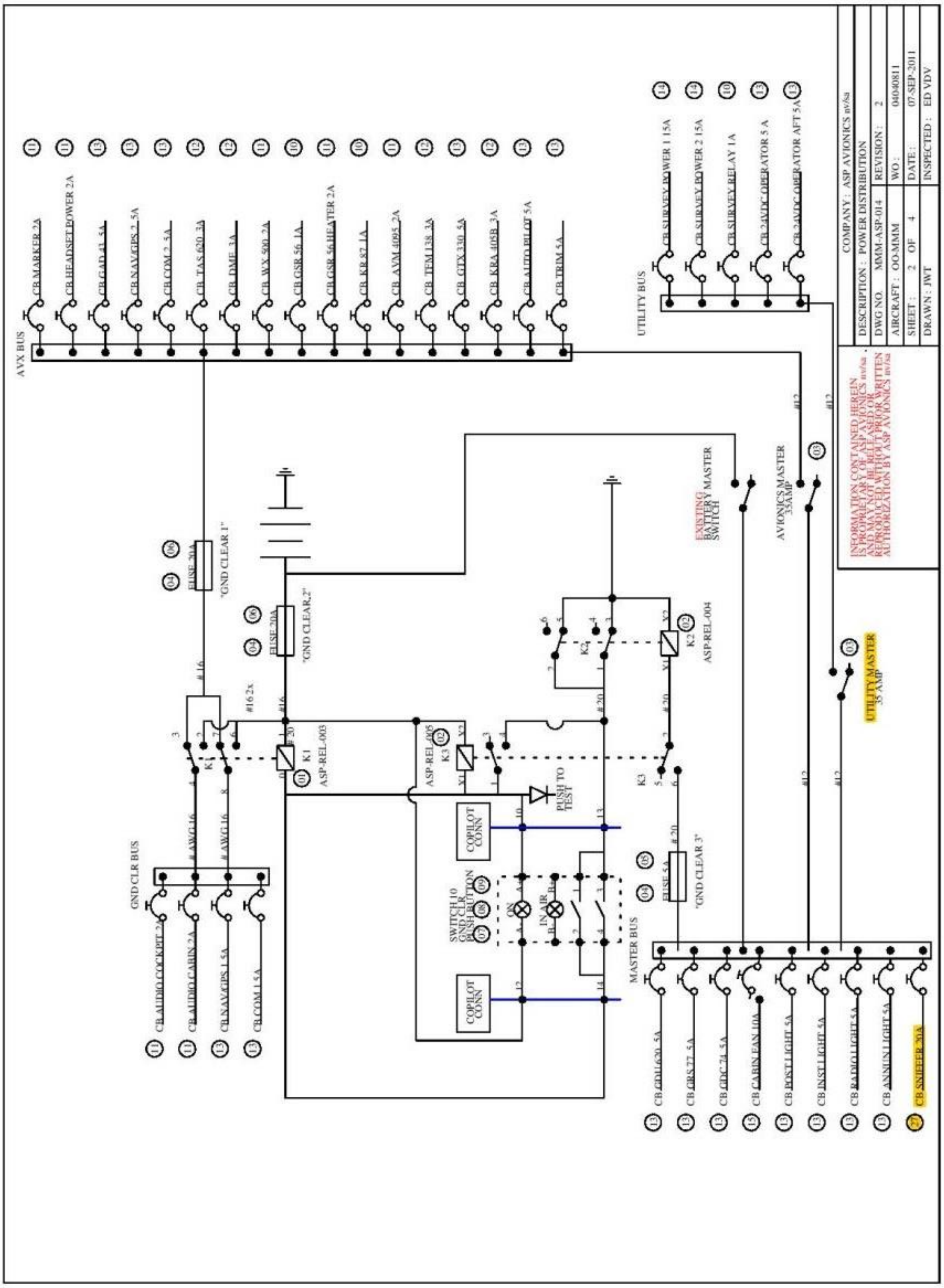


Figure 122 Wiring diagrams Survey Power

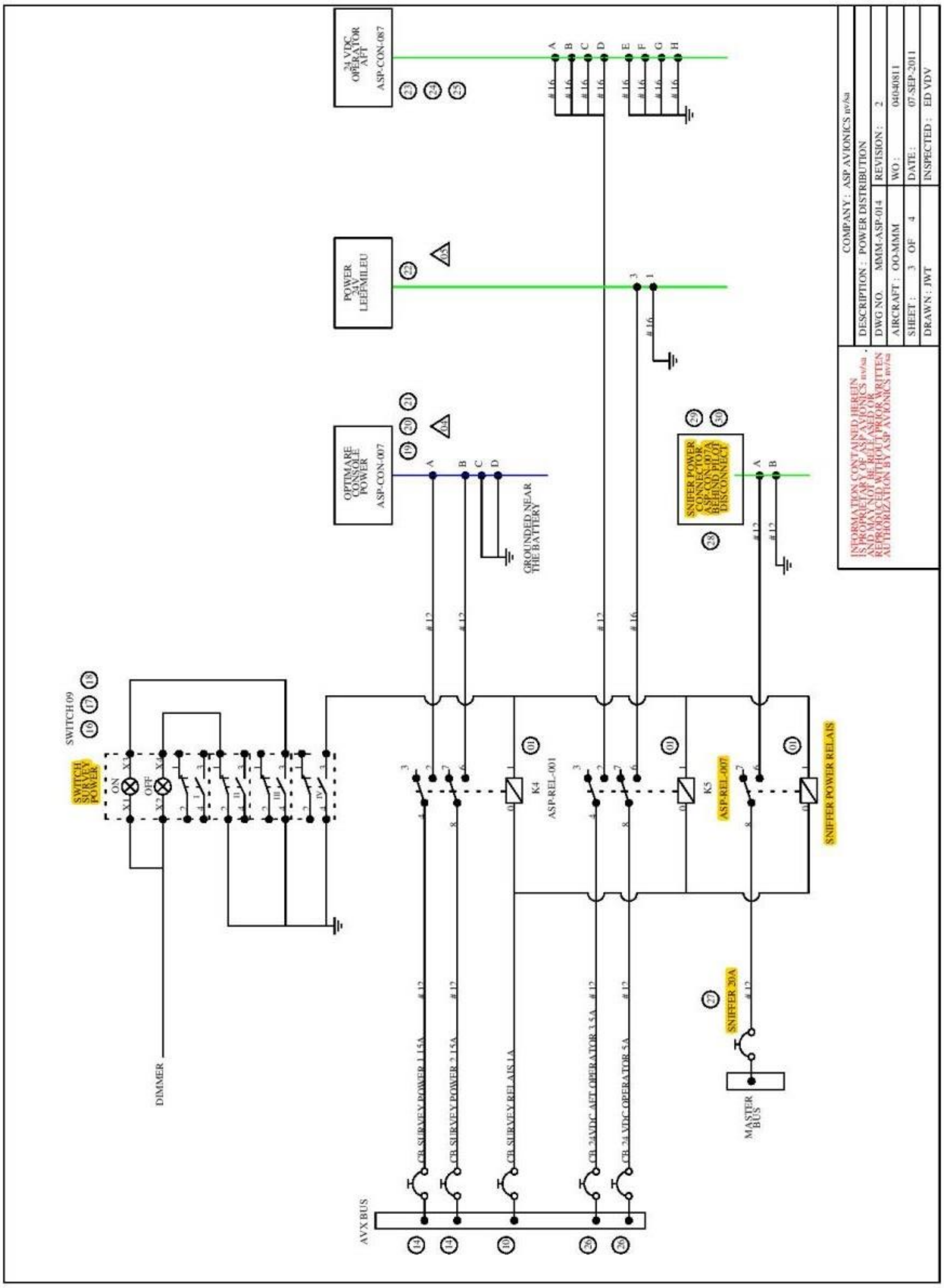


Figure 123 Sniffer Power Relay (T92P11D22-24) wiring

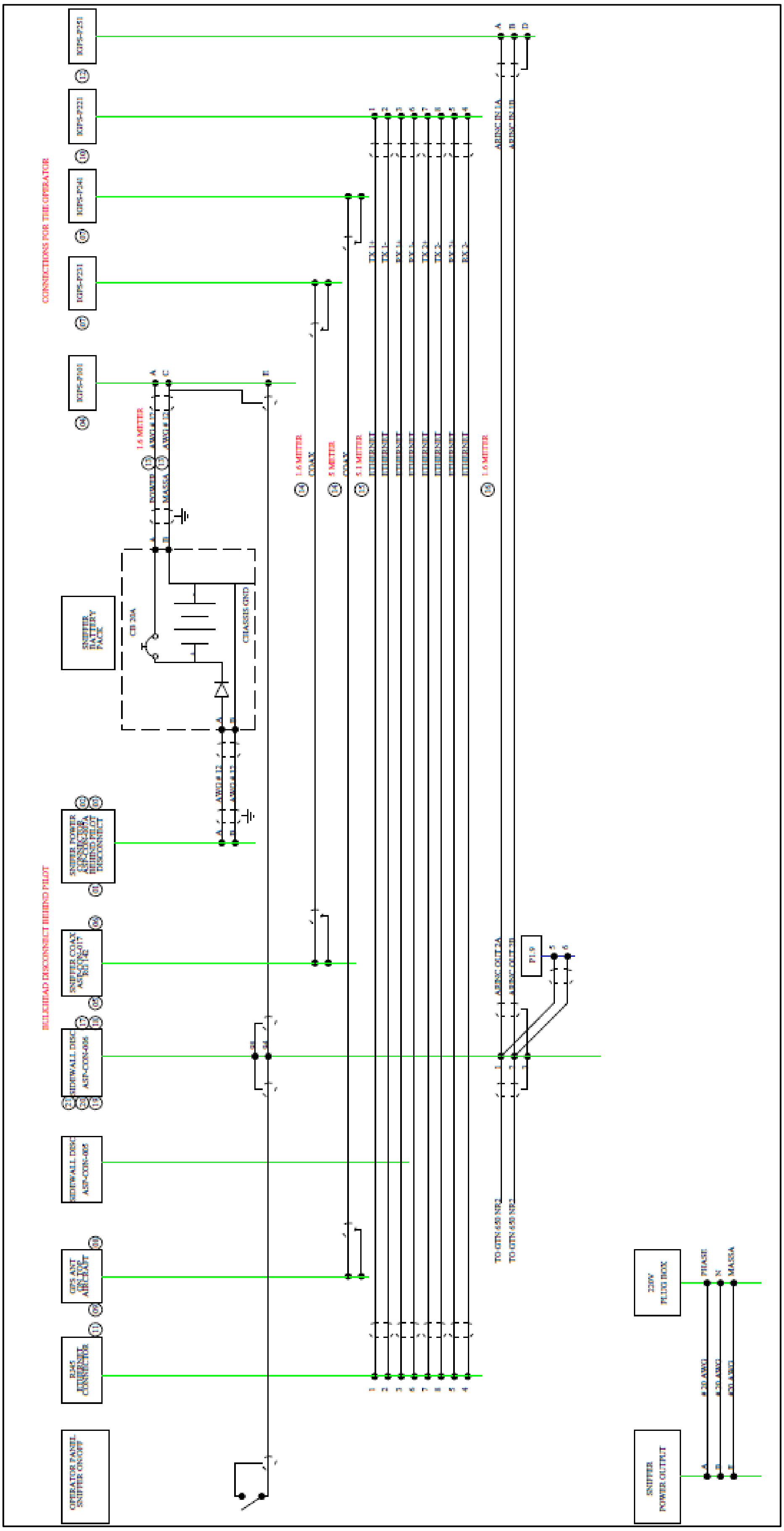


Figure 124 Sniffer battery connection

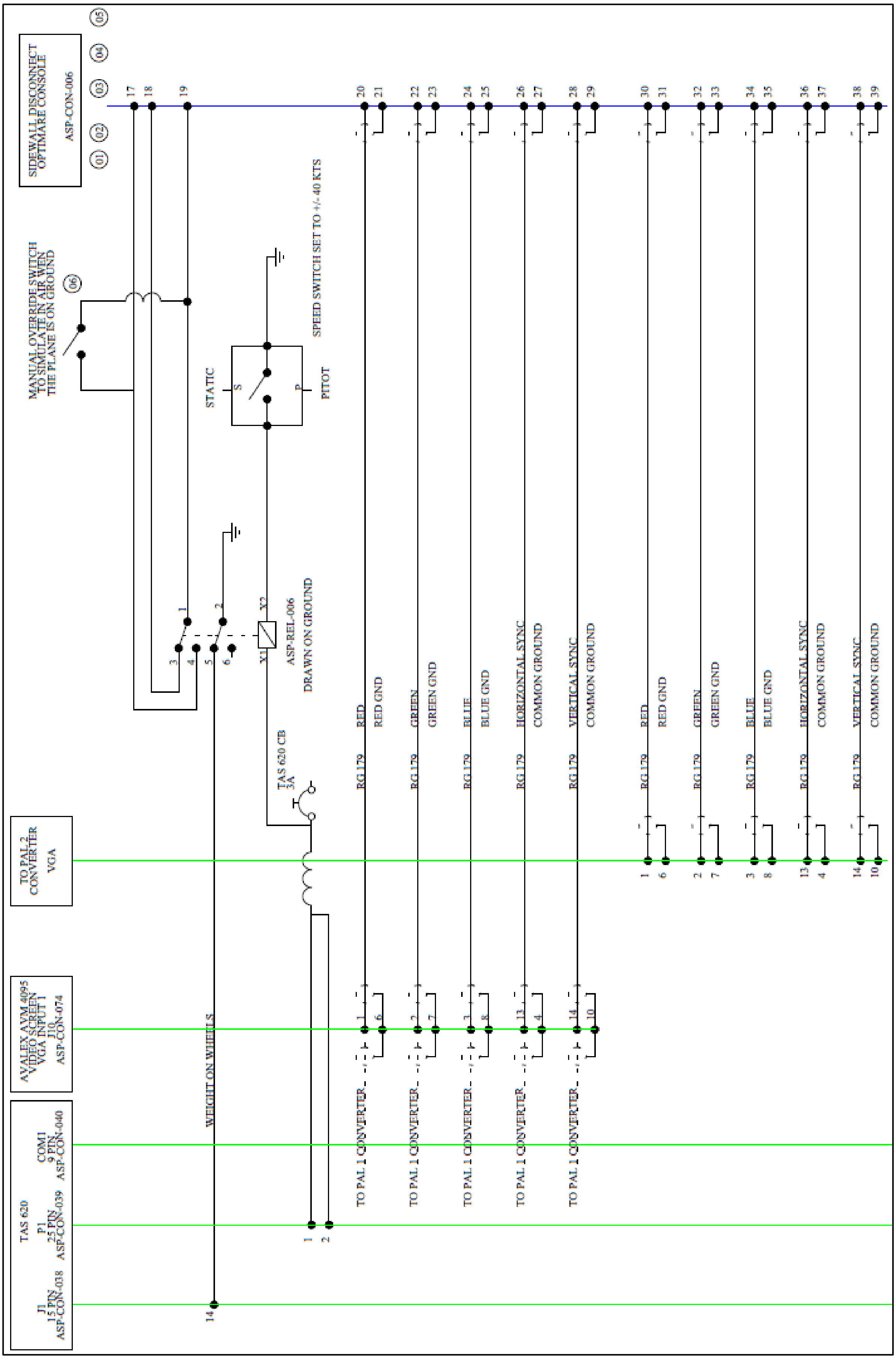


Figure 125 Video signal wiring

ANNEX C - BLOCK DIAGRAMS

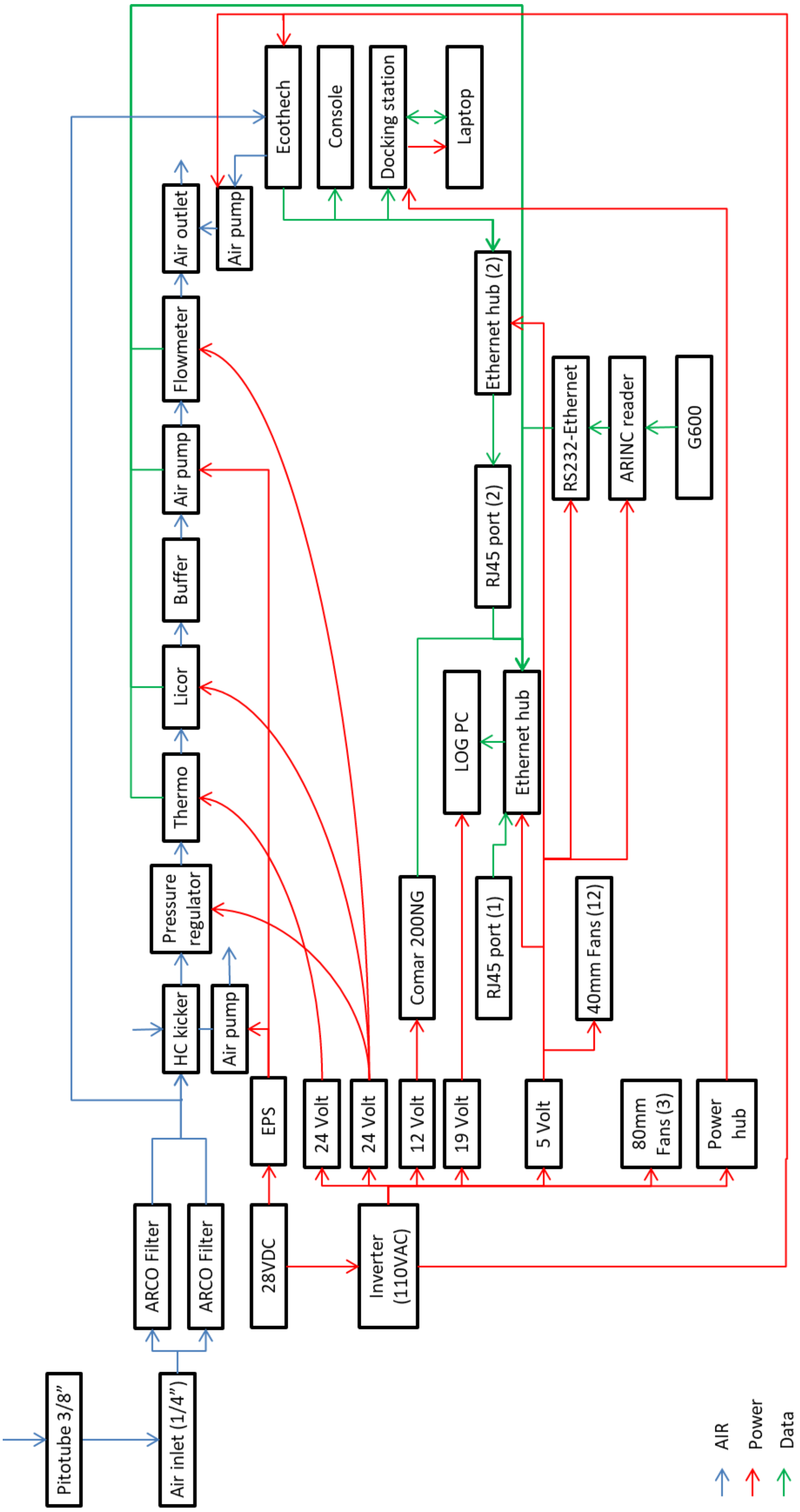


Figure 126 Block diagram Sniffer system

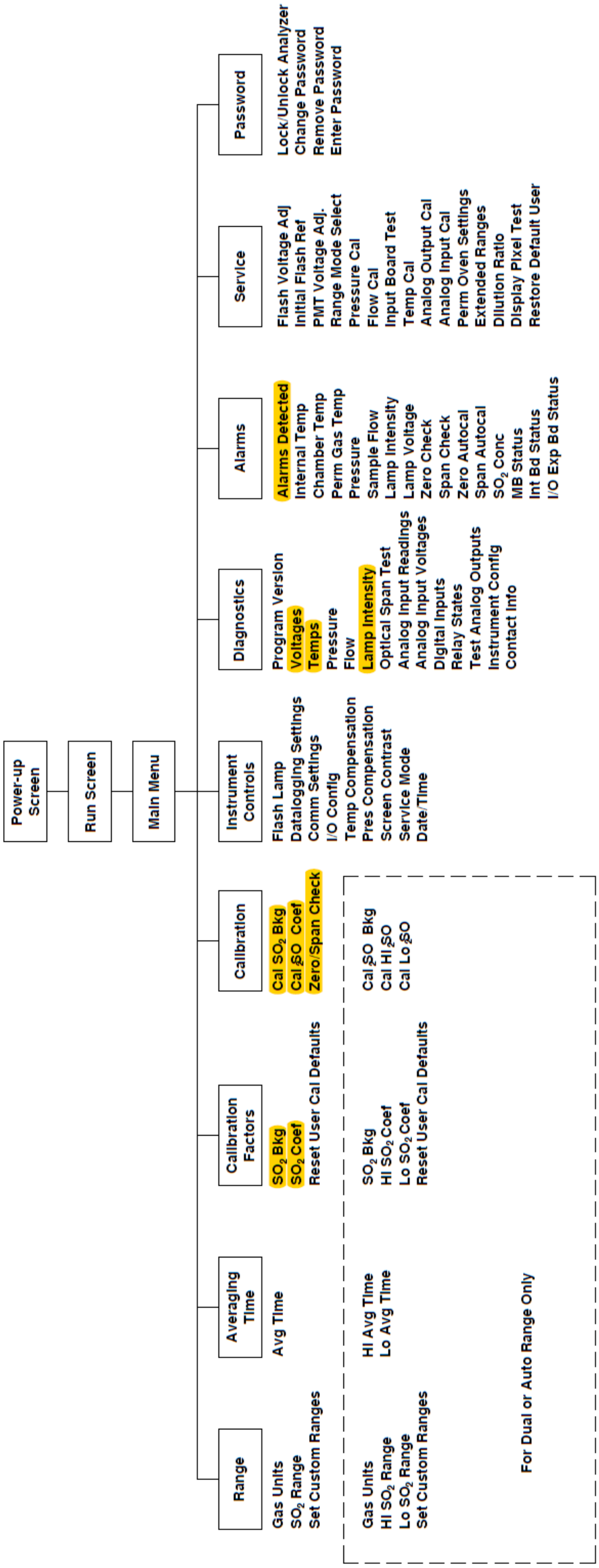


Figure 127 Menu structure Thermo 43i TLE

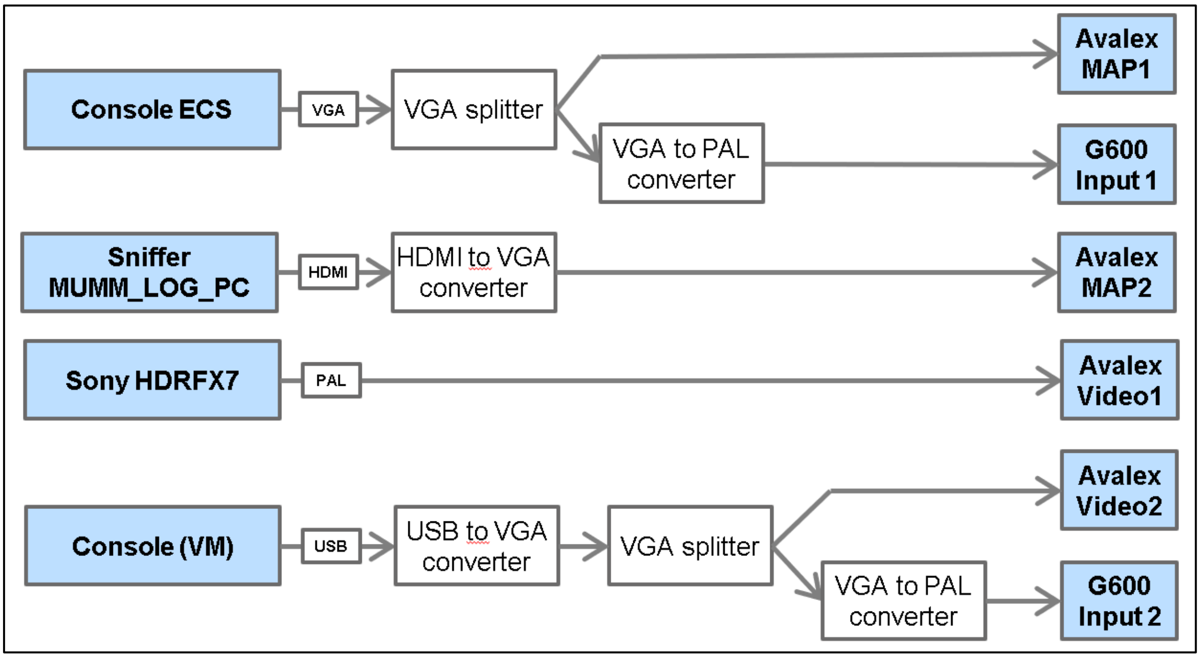


Figure 128 Video signal setup of AVM 4095

ANNEX D - SCHEMES

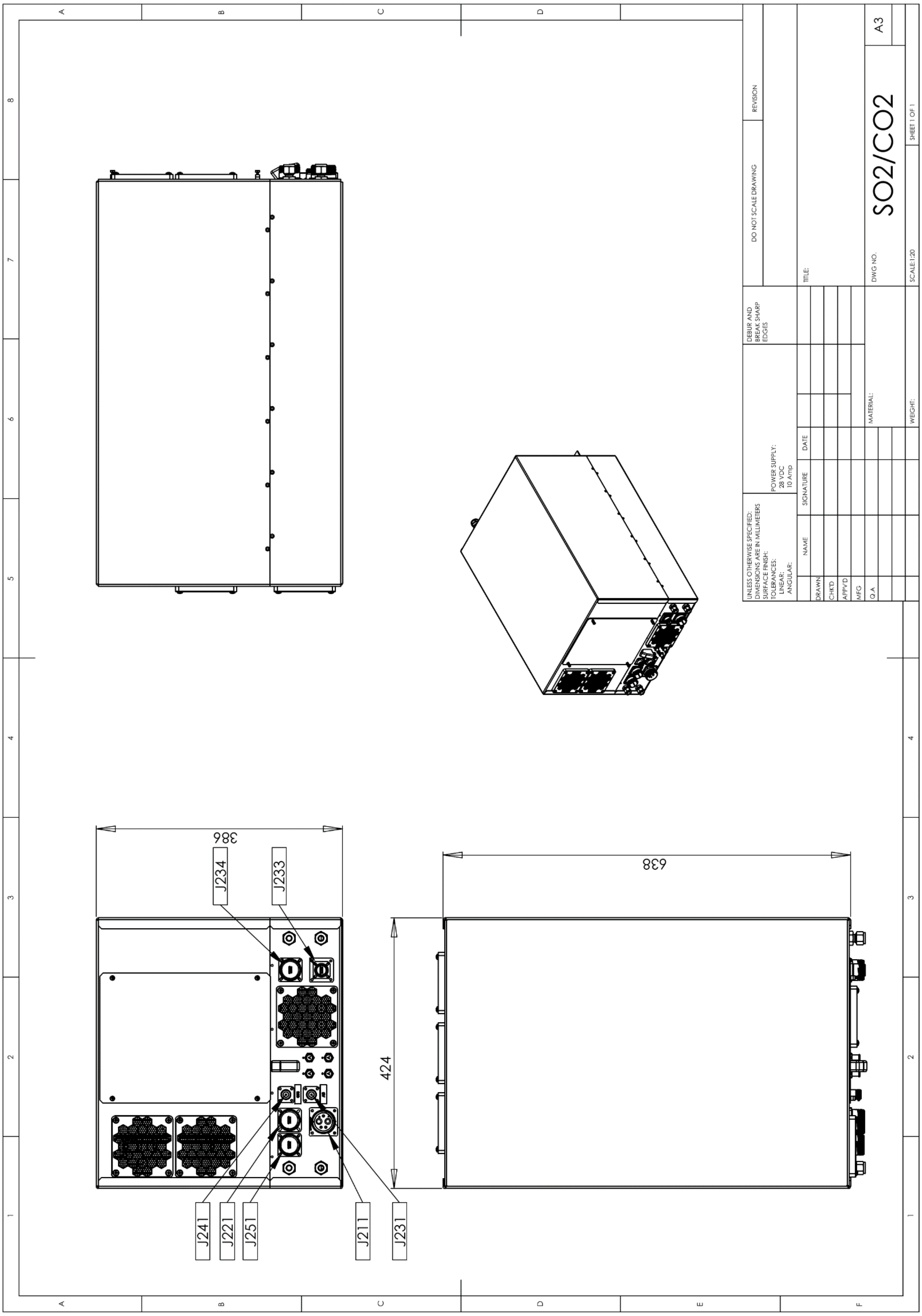


Figure 129 Technical drawing sniffer box

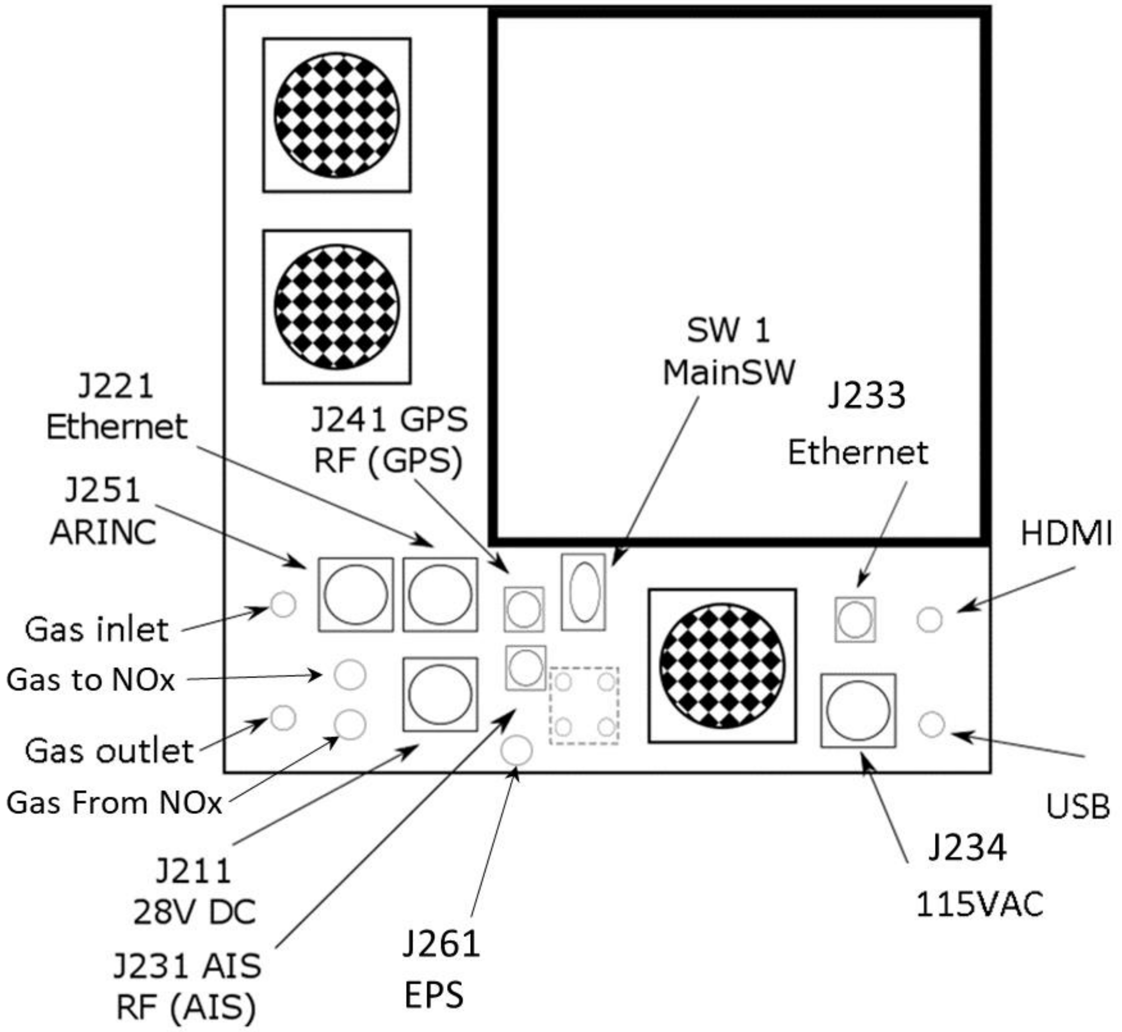


Figure 130 Drawing and picture of the connector panel on the Sniffer sensor (note J261 is missing in the bottom picture)

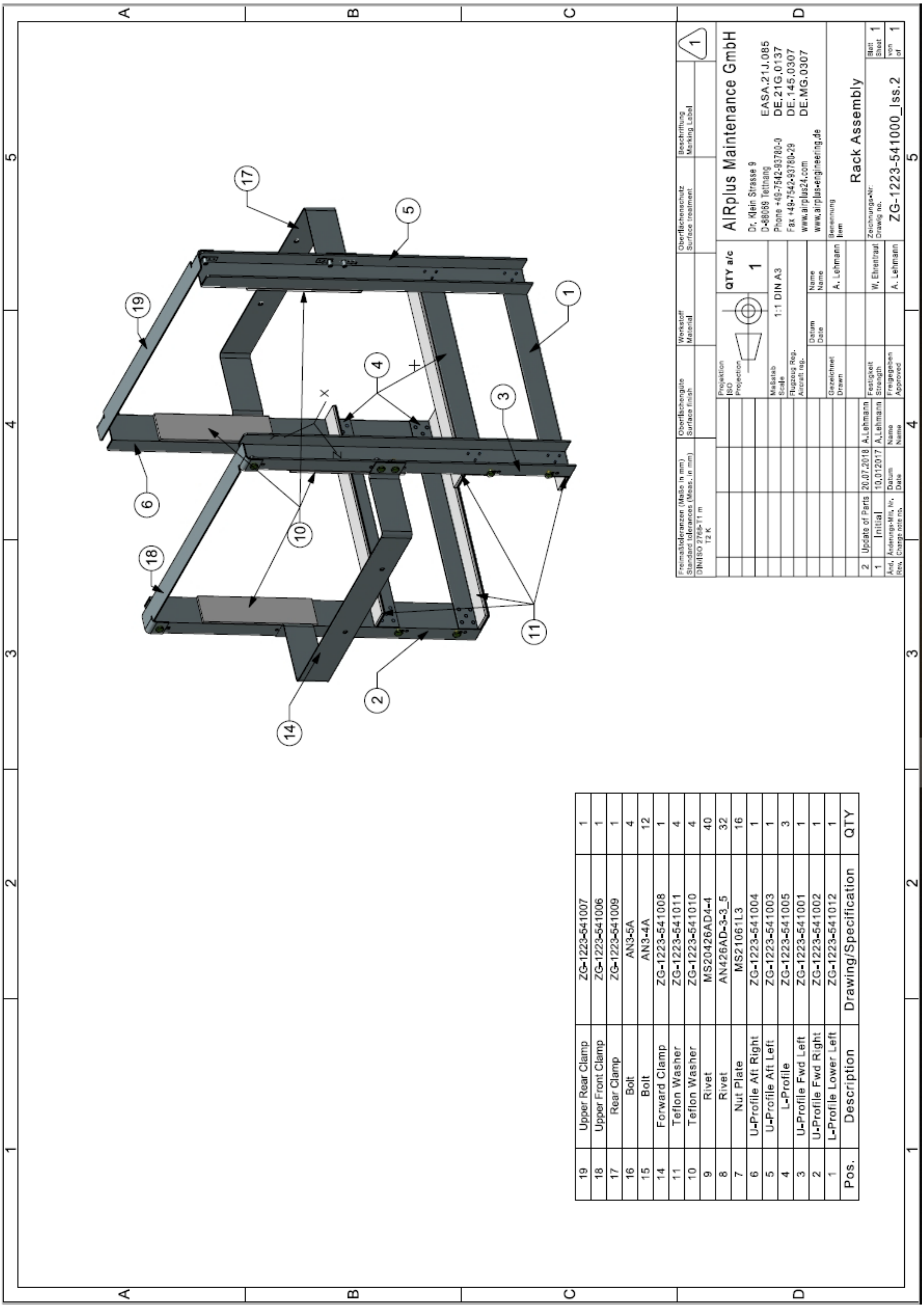
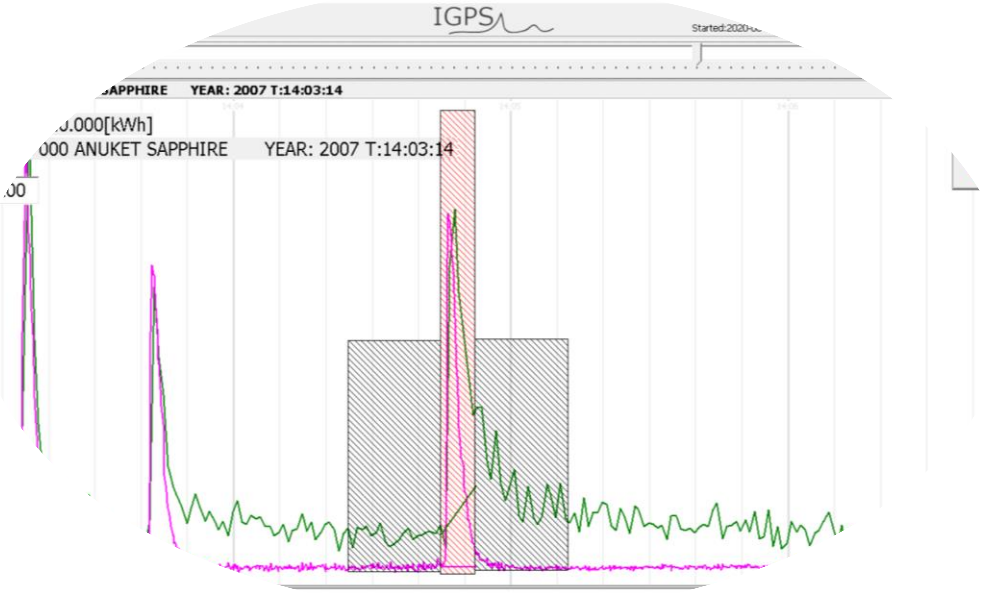


Figure 131 Scheme Sniffer rack

SNIFFER QUALITY MANAGEMENT SYSTEM

SECTION 3.

SNIFFER DATA MANAGEMENT MANUAL



REVISIONS

Revision Date	Chapter - section	Page	Description
17/01/2021	6.4 7.2	7-4	MUMM-LOG-PC moved from Section 2 to Section 3
17/01/2022	All		Adding of NOx
27/07/2022			Adding of FSC bias

ABOUT THIS MANUAL

The Sniffer Data Management Manual was developed by MUMM to be used with the sniffer installation on board of the Belgian Coastguard Aircraft, a BN Islander (BN2A) with call sign OO-MMM. The Data Management constitutes to Section 3 of the Sniffer Quality Management System (QMS). The Sniffer Quality Management System was specifically designed for the Belgian Marpol Annex VI monitoring program entailing the proper functioning of the sniffer system on board of the Belgian Coastguard Aircraft and the provision of accurate and consistent data collection. The Quality Management System consists of in total 3 Sections, Section 1 describes the operational aspects of the airborne monitoring. Section 3 consists of the data management aspects (see Figure 1). For every section a detailed manual is developed and available on the Seafile folder 1. SNIFFER QMS under the Seafile library 05-Instrumentation/05-FluxSense_Sniffer

In this manual, detailed information and step to step instructions are provided about the installation, calibration, and servicing of the sniffer sensor system. The manual is organized in different chapters and annexes to provide direct access to specific information, chapters can be toggled directly. The chapter can also be used as stand-alone guides during the different interventions in the field.

- "**Chapter 1 Internal Data structure**" describes the installation on board of the OO-MMM aircraft and the data structure of Sniffer sensor system.
- "**Chapter 2 Measurement uncertainty**" provides a detailed overview for the calculation of the FSC uncertainty.
- "**Chapter 3 Threholds for reporting**" provide the procedures to determine the thresholds for reporting.
- "**Chapter 4 Reporting of non-compliance data"** provides all information for the reporting of non-compliance data to PSC and Thetis-EU.
- "**Chapter 5 Reporting of compliance data**" describes all practical aspects of the reporting of compliant data to Thetis-EU and for third parties.
- "**Chapter 6 Reporting of annual results**" describes the procedures for the collection of data for the annual reporting.
- "**Chapter 7 Data storage and backup**" describes the procedures for the backup of the data.
- "**Annex A - Block diagram**" provides a blockdiagram of the sniffer sensor system
- "**Annex B - Configuration file**" contains the configuration file of the IGPS system
- "**Annex C - Flight report**" gives an example of a flight report

Figure 132 Sniffer QMS Structure

The sniffer sensor system manufactured by FluxSense (Sweden), consists of a compilation of components from different soft and hardware providers. This manual was composed by the scientific Service MUMM of the Royal Belgian Institute based on the different maintenance provisions of the components, applied on the specification of the sniffer sensor system on board of the Belgian Coastguard Aircraft and the nature of the Belgian North Sea Aerial Surveillance Program, as a result this manual may possibly not fully reflect the official opinion of the manufacturers.

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CHAPTER 1. INTERNAL DATA STRUCTURE

The sniffer sensor system is the complete equipment setup used for airborne Marpol Annex VI monitoring. The sniffer sensor system is installed in a BN Islander type B2-A with immatriculation OO-MMM. The sniffer sensor setup is described in detail in Section 2: Sniffer Quality Assurance manual, an overview is available in **Annex A - Block diagram**.

1.1. Sniffer sensor

The main component of the sniffer sensor installation is the sniffer sensor. The sniffer sensor was developed by Chalmers University and commercialised by FluxSense (Sweden).The sniffer sensor is a collection of different components and sensors that are installed in a custom made casing. The sensors consist of certified equipment used for ambient air quality monitoring that has been disassembled from its original case and reassembled in the sniffer sensor. In 2020 the sniffer sensor was extended with a NOx sensor which is installed in the rear part of the aircraft.

1.2. Measurement principle

The basic measurement principle consist of the measurement of the concentration of SO2 and CO2 for the calculation of the SO2 emission factor and the measurement of the concentration of NOx and CO2 for the calculation of the NOx emission factor.

1.2.1 FSC

To calculate the FSC, the SO_2 emission factor in g SO_2/kg fuel was calculated based on the SO_2 and CO_2 concentration before and in the plume. When passing through the plume, the increased SO_2 and CO_2 compared to the background (bkg) was calculated by looking at the surface area under the respective concentration plots (Balzani Lööv et al., 2014). To calculate the amount of kg burned fuel the amount of C was multiplied with the carbon content in the fuel, for marine fuels a carbon content of 87% was used (Beecken et al., 2014).

$$EF_{SO_2} = \frac{MSO_2 \frac{g}{mol}}{\frac{MC \frac{g}{mol}}{0.87}} \times \frac{10^3 \times \int [SO_2 - SO_{2,bkg}]_{ppm} dt}{\int [CO_2 - CO_{2,bkg}]_{ppm} dt} \left[\frac{g}{kg_{\ fuel}}\right]$$

To find the FSC, this formula was converted by using the molecular weight of S instead of using the molecular weight of SO_2 (Beecken et al., 2015).

$$FSC = 0.232 \times \frac{\int [SO_2 - SO_{2,bkg}]_{ppb} dt}{\int [CO_2 - CO_{2,bkg}]_{ppm} dt} [\% \ Sulphur]$$

1.2.2 NOx

The NO_x emission factor (EF_{NOx}) in g NO_x/kg fuel can be calculated by using the NO_x and CO_2 concentrations. When crossing the exhaust plume, NO_x and CO_2 concentrations will increase and create peaks compared to the background [value] (bkg) before and after the peak. The surface area of these peaks above the background of the respective concentration plots is used for the calculation of the NO_x emission factor. For the calculation of the amount of kg burned fuel, the amount of Carbon

(C) is multiplied with the carbon content in the fuel. For marine fuels a carbon content of 87% is used (Beecken et al., 2014)

$$EF_{NO_x} = \frac{M\,NO_2 \frac{g}{mol}}{\frac{M\,C \frac{g}{mol}}{0.87}} \times 1000 \times \frac{\int [NO_x - NO_{x,bkg}]_{ppm} dt}{\int [CO_2 - CO_{2,bkg}]_{ppm} dt} \left[\frac{g}{kg\ fuel}\right]$$

$$EF_{NO_x} = 3.33 \times \frac{\int [NO_x - NO_{x,bkg}]_{ppm} dt}{\int [CO_2 - CO_{2,bkg}]_{ppm} dt} \left[\frac{g}{kg\ fuel}\right]$$

According to Regulation 13 of MARPOL Annex VI, the molecular weight of NO_2 is used for the calculation of the NO_x emission factor. For the calculation of the NO_x emission in g NOx/kWh, the NO_x emission factor (g NO_x/kg fuel) is multiplied by the Specific Fuel Consumption (SFC).

$$SFC = \frac{kg\ fuel}{kWh\ BHP}$$

$$EF_{P,NO_x} = EF_{NO_x} \times \left(\frac{kg\ fuel}{kWh\ BHP}\right)$$

Based on literature and public engine data, the SFC can generally be found between 0.16 kg/kWh and 0.24 kg/kWh. In the general operations a standard of 0.2 kg/kWh is used.

1.3. Sniffer software

The sniffer system consists of Five main software applications that operate on Microsoft Windows: TCP log, IGPS Present, Watchdogs (WD), IGPS Extract and IGPS Analysis. TCP log runs on the internal computer of the sniffer and manages all communication with the instruments, merges the different data streams from the various instruments to one single data stream that is broadcast on the network to all connected client stations. Figure 133 shows how the information flows in the IGPS sniffer system. The TCP log collects the data and controls the sensors. The information is then forwarded (using the broadcast address of 255.255.255.255) to all computers on the local network. The recorded data is stored to the local disk in files in one hour blocks. IGPS Present is the software run on the operators computer, this software performs the analysis of the measured gases and presents the operator a map with all ships in the area, the watchdogs are making sure TCP Log and IGPS present are always running on the MUMM-LOG-PC. After extracting the raw data with IGPS Extract, IGPS Analysis can be used for further processing either after the flight or during the flight.

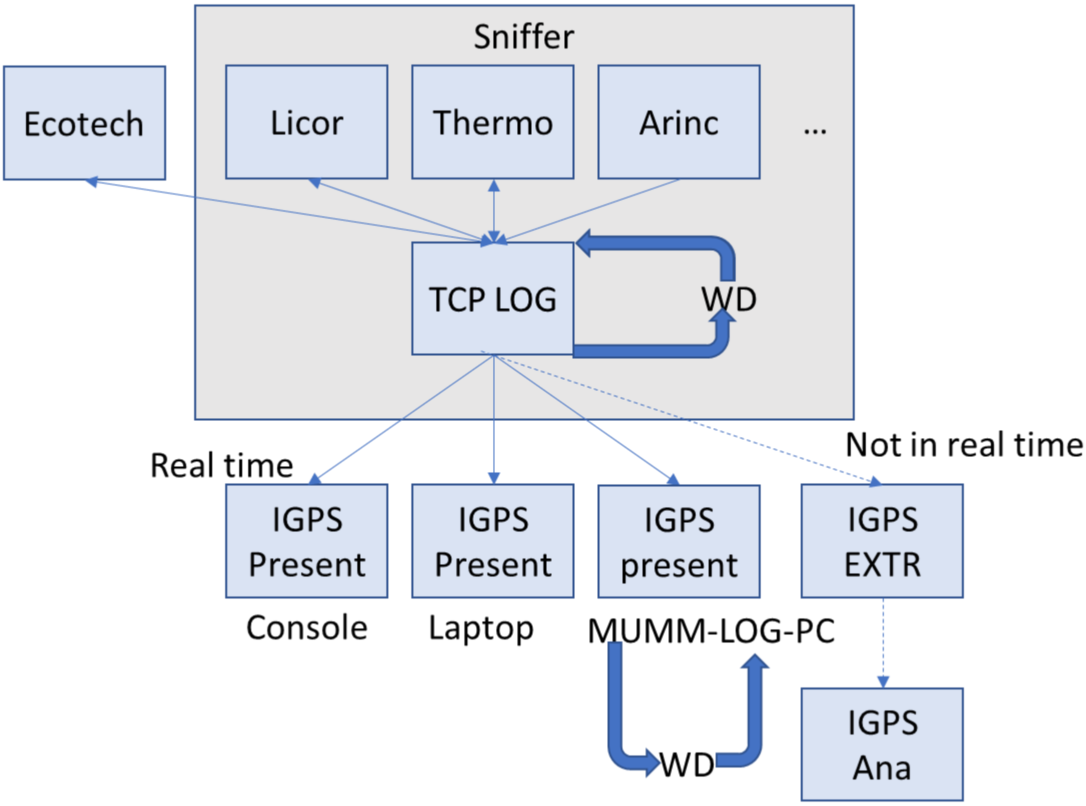


Figure 133 Schematic presentation of the sniffer sensor software

All software is installed on an "IGPS" folder which must be located directly on the "C:" drive, this folder consists of the following data for all stations:

- "Charts" Directory: folder with Open source charts of the world
- "Missions-Data" Directory: folder with generated reports of observations
- "MAIL" Directory: not used by SURV
- "AIS_EX8.exe" program: tool used for extraction of TCP-LOG files
- "AISPresent.exe" program: main software program used in flight and during calibrations
- "IPGSAna44.exe" program: software for post flight analysis (extraction required)
- "AISPresent.ini": this is the settings file for AIS present (can be read and edited using Notepad)
- "IP-configuration-SURV.txt" file: this document contains the used IP addresses for the different clients
- "Emissiondata_xxx.txt" files: are generated by the different clients (ODN-WVR, ODN-KS, ..) and contain the FSC measurements
- "Mail_Sniffer_SO2_Man_Meas.csv" file: contains the evaluation (High/Low/Not detected) of the manually marked ships
- "Comments _xxx.txt" contain the stored comments (old comment files are stored in "Comments" directory
- "wakeuplan.txt" file: contains the Mac address of the MUMM_LOG_PC in the sniffer sensor and can be used to wake up by lan
- "Optical_SO2_Man_Meas.txt" file: not used by SURV
- "STATICSHIPDATA_xxx.txt" file: contains a record of the observed ships per operator

- "borlndmm.dll", "cc32230.dll", "cc32230mt.dll", "Fetchlog.txt", "Logfile.txt", "Memo1-1.txt": are other additions files
- MMSI_Date: This file contains the Keel Laying Dates of tens of thousands of ships

For the IGPS folder on the MUMM-LOG-PC an additional directory is available

- TCP log: This directory includes all log files collected per hour

The IGPS folders of the operator laptops are synched by Seafile. This way all operators use the same software version with the same software directories and files. This is not the case for the IGPS folders on the LOG PC and MEDUSA client station, these folders have to be updated manually when new software versions are configuration settings are available.

The operational use of the software, the measurement data collection, reporting and basic post flight processing are described in Section 1 of the Sniffer QMS. The software aspects for maintenance features, the software troubleshooting and the collection of quality assurance and maintenance data (e.g. calibration data) are described in Section 2.

1.4. IGPS present

This is the main application for the collection of sniffer measurements and may also be referred as IGPS real or AIS Present, all functionalities are described in detail in Section 1 and Section 2. This software has following data-output or will alter following files:

- AISPresent.ini
- Emissiondata_xxx.txt files (one per operator)
- Mail_Sniffer_SO2_Man_Meas.csv
- Comments _xxx.txt (per hour)
- STATICSHIPDATA_xxx.txt (one per operator)

Operators should be aware that when opening the IGPS present software some of these files are used and can be modified by the software, therefore it is advised not to open IGPS presenter on different Operator laptops on the same time or before a synching has been completed. (This does not apply the IGPS software on the Console and MUMM-LOG-PC as they do not have synched libraries).

1.5. AISPresen.ini

The AISPresen.ini (see **Annex B - Configuration file**) contains the configuration parameters for the ASIPresent.exe software. The parameters should be only changed when the IGPS software is closed. For safety reasons it is advised to make a backup of the configuration file before changing it. The ini file can be opened in notepad. Some parameters are changed from the software (eg. Displayed graphs, compass, AIS info box, …), other parameters can only be changed in the software itself. Following parameters might need to be changed manually when deemed necessary:

- NO and NOx Delay (1.5.1)
- NO/NOx ratio (1.5.2)
- MID data (see 7.3.1)

1.5.1 NO and NOx delay

As the NOx is operating in a lower pressure and flow, the airflow is split after passing through the filters (but before the pressure regulator). In addition the NOx sensor is installed at ca 6 m from the other sensors, by using a smaller tube size toward the NOx (1/8") this difference is somewhat reduced. Nevertheless this still results in a different time before the air is passed through the NOx sensor compared to the SO2 and CO2 sensor. In addition the change in flow or pressure in the SO2 and CO2 circuit may also change the time difference between the SO2 and CO2 signal compared to the NOx signal. To correct for these delays 2 parameters have been introduced defining the delay time. To correct for these delay time, the plots on the SNF graph can be used to estimate the delay, by adjusting the delay time iterative one second at a time, the delays on NOx and NO can be removed. This should only be performed when changes are made in the tubing length or in the flow. The NO has currently a delay of 4 seconds and the NOx a delay of 5 seconds (see highlighted section in **Annex B - Configuration file**), the difference is caused by a limited length in tubing between the two modes. In case the delay loop is installed the difference between the two is ca. 5 seconds. Different delays for different operation modes are available in the Delays.xls file on the IGPS folder

1.5.2 NO/NOx ratio

The NO/NOx ratio is used to define the concentration of NO when the NOx sensor is in NO mode and vice versa to estimate the amount of NOx when the sensor is in NO mode. As the ratio is not a fixed constant the sensor is generally operated in NOx mode, only when a possible violation is observed for FSC, the sensor is set to NO mode to calculated the NO interference more precisely.

1.6. TCP log

The software TCPlog has is continuously logging the data from all the available instruments with a sampling period of approximately one second (5hz for the Licor7200). This includes data from the gas analysers, wind information, AIS receiver and GPS. The log program is the only part of the tailored IGPS software that is used to communicate directly to the sensors. TCP-log is only installed on the MUMM-LOG-PC. The log program also handles certain specific sets of commands from the IGPS Present software to the sensors.

TCP-log program is also responsible for the broadcasting of communications entered by any of the users from one client station to all other active IGPS Present windows on other client stations (e.g. comments, targetting or tagging of ships). In this sense, the TCP log avoids user conflicts when multiple operators simultaneously access the sniffer box. The recorded data is storage through text files at regular intervals of 1 hour using the following format: YYYYMMDD-HHMMSS.txt, at ca. 30MB of data per hour. The Storage location typically is C:\IGPS\TCPLog, though this location can be modified by changing the setting of the configuration file (Appendix 2). The TCP Log must be started by loading the executive file: C:\TCPLog.exe this can be done by using a command window, a .bat file, a shortcut, or through the watchdog software (see 1.7 Watchdog). To manually end TCP log, open the program from the task bar and close the program, or end the task using the task management. The watchdog will pop up and must be closed as well, after which the TCP log will open again and must be closed once more.

1.7. Watchdog

A watchdog timer (WDT) software is configured as part of the startup process of the MUMM-LOG-PC. Once the WDT is running it will handle the start of both the TCP Log and the IGPS Present software at the beginning of the measurements, or in case of an unexpected crash of either the TCP log or IGPS Present. If a configuration file must be changed or for updating the IGPS software, the WDT and thereafter the TCP Log and IGPS Present must be manually stopped. The WDT can be manually restarted at the IGPS location:

- TCP Log: C:\IGPS\TCPLog.exe
- IGPS Present: C:\IGPS\AISPresent.exe

1.8. Analysis of LOG files using AIS Extract

The TCP Log software storages all the raw data and calibrations in a semi binary file at regular intervals of 1 hour using the following format: YYYYMMDD-HHMMSS.txt. Every single line of this file contains an individual measurement and a header that includes the GPS-logging time and the instrument network parameters. The IGPS Extract software is a tool that interacts with the raw data in order to generate user friendly individual text files corresponding to each of the logged instruments.

These files can be used of detailed analysis per sensor or for post flight reprocessing with the IGPS Analysis software. Follow the following procedure to extract data. Data can be extracted for individual log files (per hour) or log files can be combined during extraction. Note that when extracting and combining multiple log files, extraction time will be notably longer.

SOP 3.1. To extract log files

1. Open AIS.EX.8.exe
2. Select file(s)
   a. Select start,
   b. browse to LOG directory
   c. select the log file(s) you wish to extract (organized according to date and time),
      - Multiple files can be loaded to create combined extracts, this will lengthen the extraction process time
   d. Select open
3. Select the output directory (create a new one or browse to existing directory)
4. Extraction will begin, when all data is extracted a notification “Done” will be displayed
5. All sensor data will be available in TXT files

The extracted data can either be analysed using the IGPS Ana tool. It is also possible to look into the individual sensor data using Excel or another data or spreadsheet tool (R, Statisitca, …). Following TXT files will be created in the output folder

- EXTR-AIS.txt: these are the altering data of the ships (posting, speed, direction … of moving ships)
- EXTR-AISGPS.txt: these are the GPS coordinates of the sniffer (the track)
- EXTR-AISGPSPos.txt: these are the GPS coordinates of the sniffer (the track)
- EXTR-AIS.txt: these are the static data of the received ships (name, IMO, dimensions…)
- EXTR-ARINC.TXT: This is the ARINC data collected by the Sniffer sensor
- EXTR-CAL.TXT: consist of the software calibration factors
- EXTR-Comments.TXT: are the comments created during flight

- EXTR-Licor7200.TXT: the raw data exported from the LICOR7200 sensor
- EXTR-SO2.TXT: the raw data from the Thermo 43i TLE
- EXTR-Serinus40.TXT: the raw data from the Ecotech Serinus 40
- EXTR-WIND.txt: This is the wind information collected through ARINC

More files are created for other sensors and equipment, but are not used in the sensor setup of the Belgian Sniffer, these files have zero values, but should not be deleted.

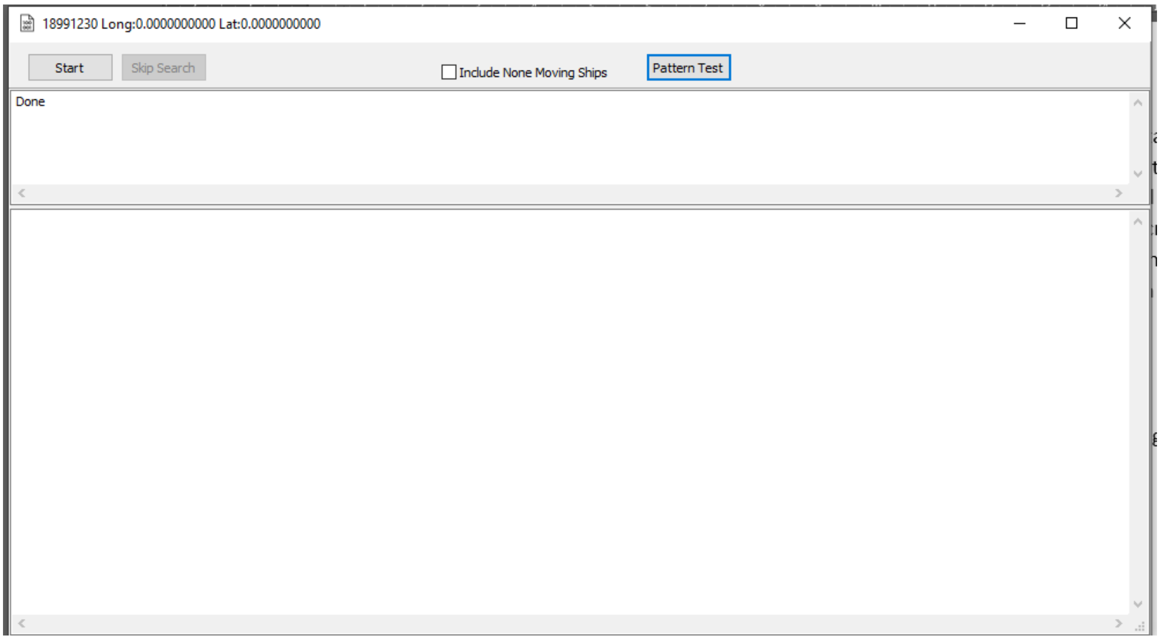


Figure 134 IGPS Extraction software

1.9. Loading extracted data in Excel

Once the data is extracted, the raw data can be imported in a spreadsheet using Excel. For CO2 and SO2 the gas measurements are available in a sperate column, but for NOx a transformation needs to be performed.

SOP 3.2. To import the extracted data

1. Extract the data of the concerned log file (see 1.8 Analysis of LOG files using AIS Extract)
    a. Import the log file
    b. Open “Calculation T90.xls” file
    c. 05-FluxSense_Sniffer\0. QMS\3. SNIFFER DM\Data analysis\T90
    d. Open Import sheet
    e. Go to Data>Get Data>Legacy Wizards>TXT (legacy)
    f. Select EXTR-SO2.TXT, EXTR-LICRO7200.TXT or EXTR-Serinus40.TXT
    g. Use comma “,” as separator
    h. Select finish
2. Copy the gas and time concentration to selection sheet
    a. For CO2
        - column AX will give the CO_2 in ppm
        - column A will give the time of the sniffer (per second), column L will give the sensor time up to 0.1 sec for T90 calculations use column L
    b. for SO2

- column F will give the SO_2 in ppb
- column A will give the time of the sniffer (per second)

c. for NOx

- column D will give the NO in ppt in scientific values
- column J will give the NOx in ppt in scientific values
- column A will give the time of the sniffer (per second)

SOP 3.3. To transform the NOx data

1. Select the columns D and J and click ctrl+h, write '= and select replace all
2. Split data, use "+" as separator and copy to a new column
3. Split data use "-" as separator
4. Create a new column that either contains the negative values (add -) or positive values for the exponents
5. Combine the value for the measurement with the exponent, devide by 1000 to arrive to the concentration in ppb

Note: excel templates exist for the automatic import of extracted files for NOx, CO2 and SO2 under T90 folder

1.10. IGPS Ana

With this software tool extracted data can be reprocessed, this can be useful for detailed analysis of non-compliant vessels. The advantage of reprocessing the data through the Analysis tool over the replaying the flight with the IGPS presenter tool is that the Analysis tool allows scrolling through the data and maybe therefore more user friendly for reprocessing of large amount of measurements. Another advantage is that the start and end times can be defined for each sensor, which may give a slightly higher accuracy (although the difference is in most cases neglectable).

1.10.1 Visualizing measurement data

After extracting the data with IGPS Extract, the measurement data can be loaded and analysed using the IGPS ANA tool. The user can interactively navigate along the full measurement time or choose to look for a specific plume or ship (Figure 137):

SOP 3.4. To load data

1. Open IGPSAna44.exe
2. Select start
3. Select folder with extracted data
4. Select output folder (use existing or create new)
5. OPTIONALLY: select folder with Emission data (use IGPS folder for recent data)
6. Data will be loaded

SOP 3.5. To scroll through the data

1. Scroll through the mission using the green arrows in the navigation bar
2. Move cursor over one of the two plots
3. When moving the cursor over the plots the aircraft will be moving over the moving map
4. The name and position of the monitored vessels are visual combined with the position of the aircraft on the moving map
5. The plots and moving map can be zoomed either by using the zoom bar, or by a double click on the CO2 plot.

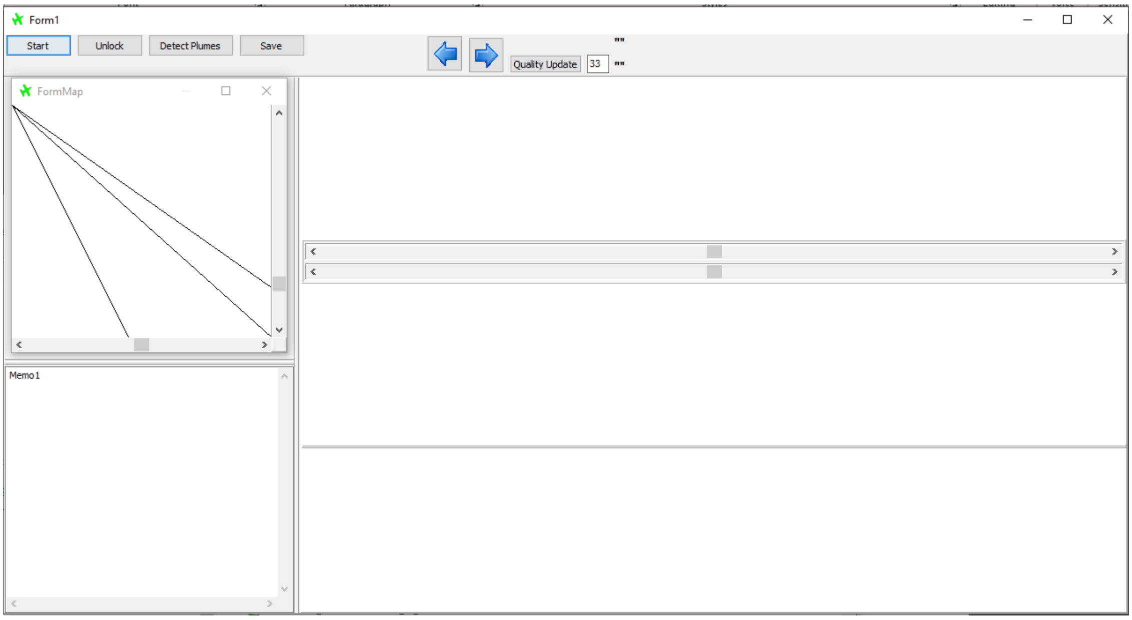


Figure 135 To load data click on start

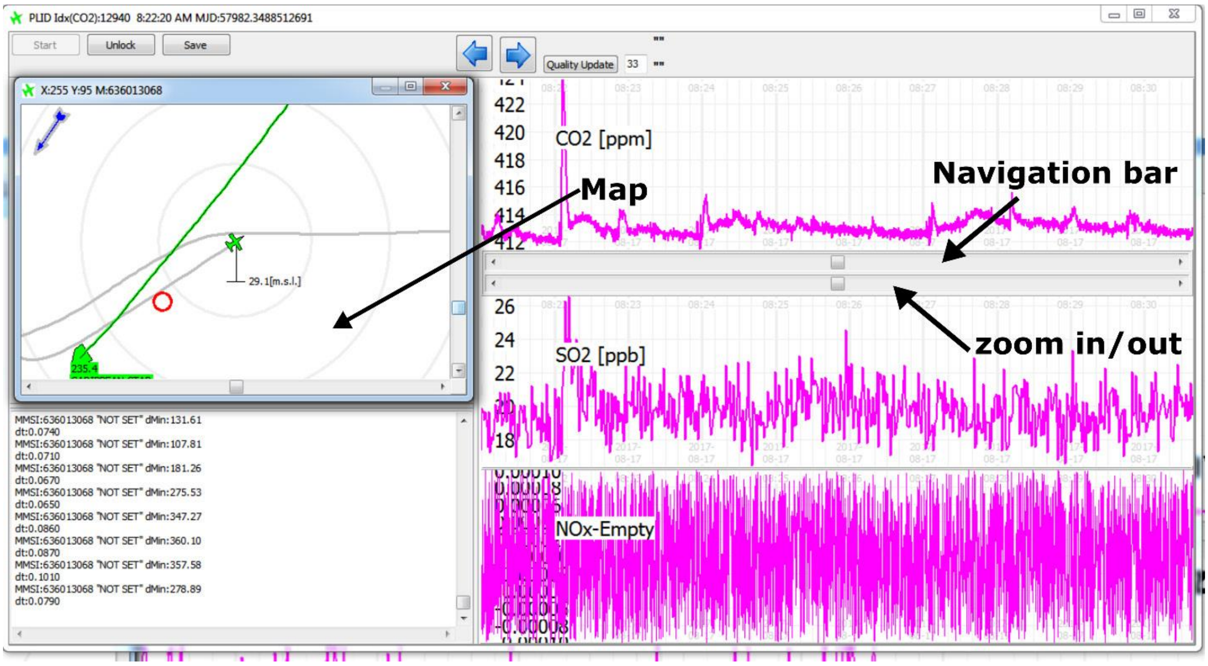


Figure 136 Data view of IGPS ana after loading data

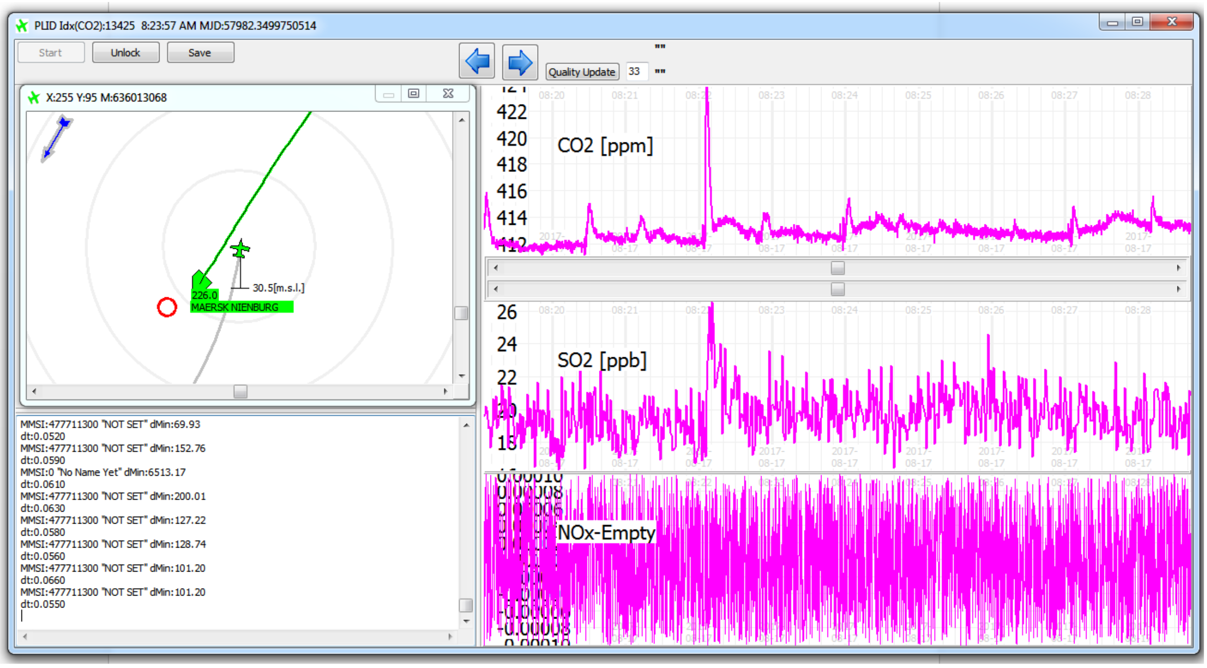


Figure 137 Moving the cursor over the graph will alter the moving map, to show the position of the aircraft corresponding to the time on the graph

1.10.2 Creating new plumes

In addition to analysing the measurement data, new plumes can be measured and assigned to ships.

SOP 3.6. To create a new plume

1. Locate the plume using the cursor and navigation bar
2. Right click on the upper plot
3. A menu appears with following options
    a. New Plume
    b. Zoom Extent (this will reset the zoom to the original state)
    c. Undelete Plume (this will restore a previously deleted plume)
4. Click "New Plume"
5. Go to the map and click right, a window will popup with 3 options
    a. Use This Ship:
        - IGPSAnalys estimates the most likely ship corresponding to the selected plume based on the wind conditions.
        - However, if there are multiple ships available, it is possible to add uncertainties per ship
    b. Unknown Ship: This will Labels the plume as coming from a "No name" vessel.
    c. Cancel: Exit this Menu.

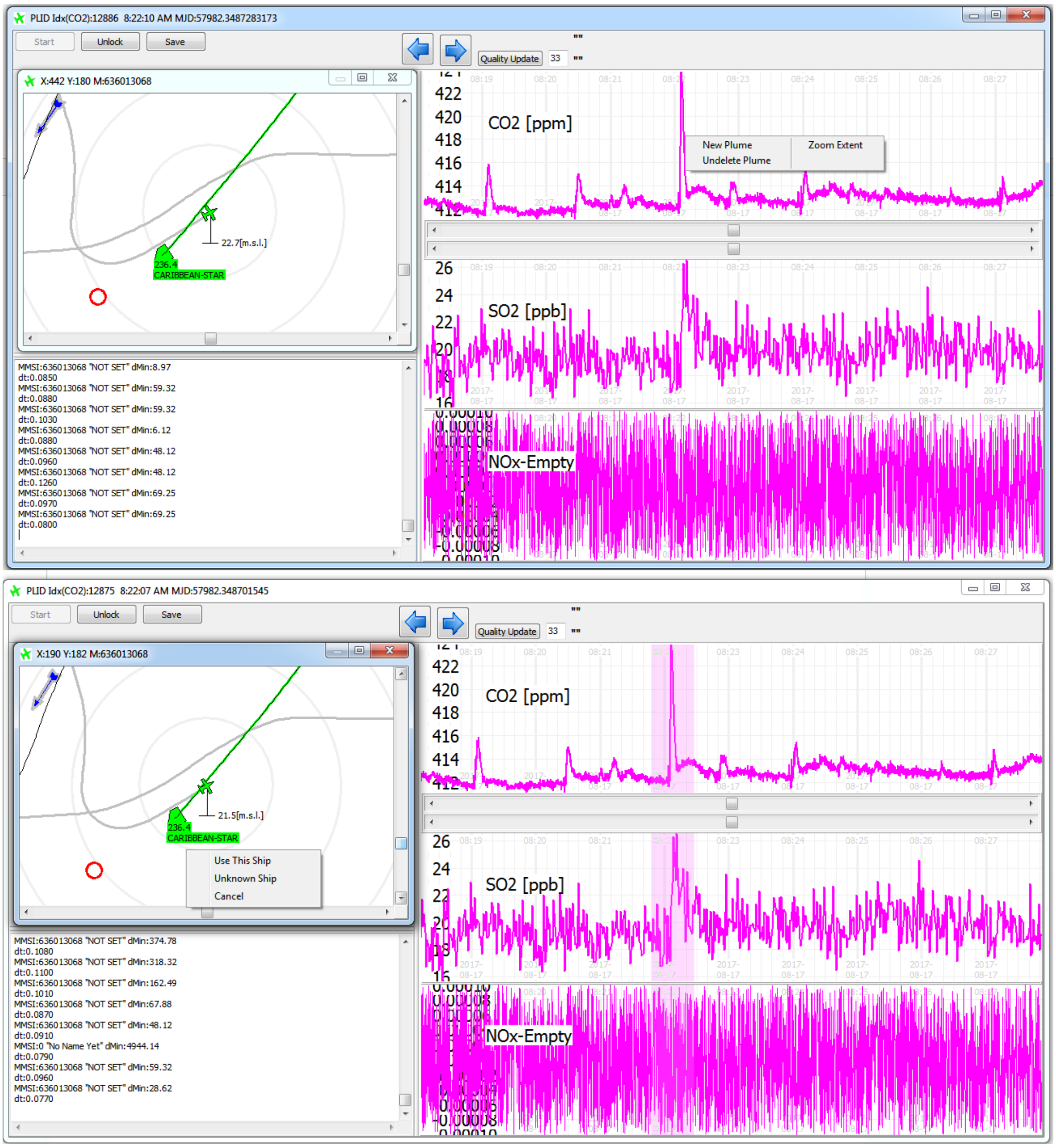


Figure 138 Right-click pop up menu prior to creating a new plume (upper) and assigning the plume to a ship (lower).

1.10.3 Calculating emission factors

After a new plume is created, the base line and the plume start and end limits can be adjusted. This similar to the plume assignment as in IGPS present, but with the possibility to either align the different gasses or to choose different start and end position per gas.

SOP 3.7. To recalculate FSC and NOx

1. Select the start and end position of the SO2 and CO2 plots corresponding to the identified plume
2. Sometimes, this procedure may require to zoom in the plots
3. At the upper panel, the output S[%] is the FSC without NO compensation, the S(NO)[%] is the FSC with NO compensation

4. The FSC and NOx value will be updated when changing the baseline and start and end position of the plumes on the plots
5. An automatic Quality level is assigned
    a. A medium quality level lies between 30 to 66 %
    b. A high quality levels lies between 66 % to 100 %;
    c. otherwise the quality is labelled as low.
6. If the pre-estimated quality flag is not satisfactory, it can also be manually changed by inserting a new value and pressing the button Quality update in the upper panel.
7. The parameter plume index increases every time a new plume is created.

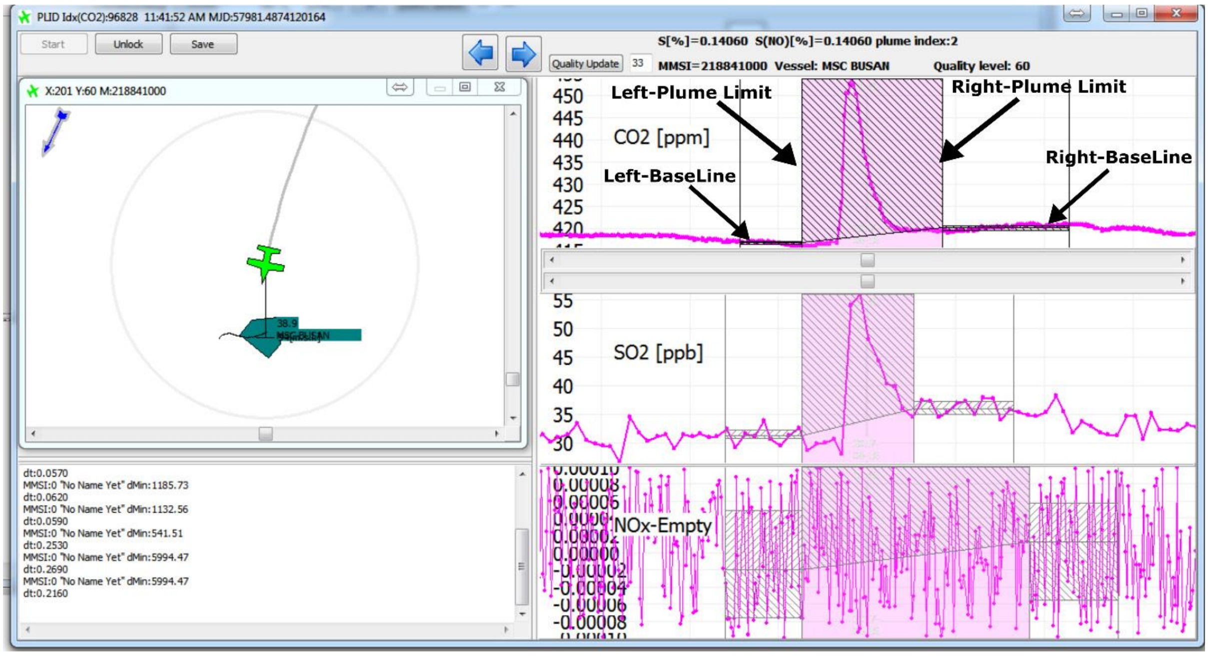


Figure 139 Setting plume delimiters

1.10.4 Checking existing plumes

After the plumes have been created and the FSC and NOx have been calculated for the different plumes it is still possible to adjust plume delimiters and reprocess the emission calculations (in comparison, this is no possible with IGPS Present).

SOP 3.8. To redefine start and end position per gas

1. The buttons with the two arrows allow to move the along the plots following the corresponding plume index
2. A right click on any of the already created plume markers on the SO2 or CO2 plot will pop up a menu with the following options:
    a. Align Left Like This: the other plume marker will be adjusted to the left plume limit and base line
    b. Align Right Like This: the other plume marker will be adjusted to the right plume limit and base line
    c. Align Both Like This: the other plume markers will be adjusted to both baselines and right/left limits
    d. Delete: Only the marker of the CO2 will be deleted, though the plume is not going to be saved. This can be reverted by the previous mentioned option Undelete Plume.

e. Reselect Ship: It allows to assign a different ship to the plume as previously shown.

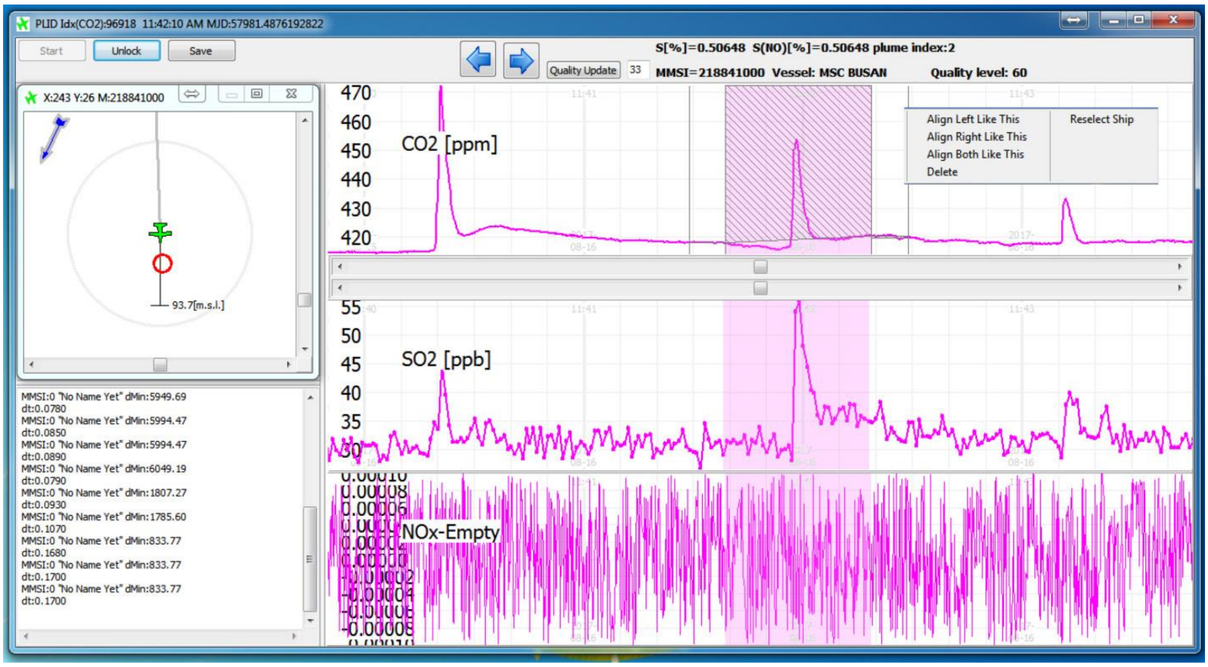


Figure 140 Pop up menu for created plumes

1.10.5 Reanalysis including the plumes emissions file

If the Emissionsdata_User.txt is available, it can be selected during the loading data (step 5 in 1.10.1). If the selected Emission file contains plumes between the time interval corresponding to the loaded extracted files, the plume markers that were created in flight, the corresponding ships and FSCs will be added. It is advisable to double check if the plume delimiters are properly aligned and adjust were necessary.

When the reanalysis is completed, press the button Save and the results will be storage in the previous selected output directory. The result consists of the following files:

- AUTO-EMI-OUT YYYYMMDD-HHmmss.txt: This files contains plume data that the IGPSAnalys can read in order to load a previously saved reanalysis.
- DYYYYMMDD-HHmmss.EMF: This files contains graphic metadata for each plume.
- MAIL-EXTENDED-EMI-OUT YYYYMMDD-HHmmss.csv: This files contains the reanalysis results of all the plume sorted in a CSV format.

1.11. Internal signal wiring

A standard 5VDC 8 port RJ45 Ethernet hub (MXU85A0001) is used to connect all the different Ethernet connectors from the components to the internal computer and client stations. The internal main IP addresses in the sniffer sensor are displayed in Table 7.

A Zotac Zbox Nano ID64 mini pc is installed in the sniffer,this mini pc is further referred as the MUMM_LOG_PC. The MUMM_LOG_PC centralizes the data acquisition and data output to the different client users via Ethernet. One USB port is connected to the external USB connector, this can be used to connect external devices (keyboard, mouse, drives, …) or for troubleshooting. The HDMI output of this PC is connected to an external HDMI connector and used for the visualisation of the IGPS navigation charts to the cockpitdisplay (VGA2 on Avalex AVM 4095) via an HDMI to VGA converter which is installed outside the sniffer sensor.

Table 14 IP addresses used in the sniffer sensor

IP address	Component	Port
192.168.1.9	MUMM_LOG_PC	
192.168.1. 95	Licor7200	7200
192.168.1.201	Thermo TLE 43i	Command: 9880 Stream: 9881
192.168.1.110	Comar AIS+GPS	10001
192.168.1.102	Bronkhorst Flowbus	1471
192.168.1.130 (CPC-3787) 192.168.1.106 (CPC-3787-RS232)	Bronkhorst pressure control: Ethernet to RS232	23 1470
192.168.1.121	ARINC receiver	9760
192.168.1.213	Ecotech Serinus 4.0	Serial port 97

To access the internal MUMM_LOG_PC, a remote connection can be realized using TeamViewer (V12) or Windows remote desktop. The IP address of the MUMM_LOG_PC is 192.168.1.9 with login name "MUMM" and password "mumm". To enable this connection the IP configuration of the client stations have to be adjusted. For more information on the configurations and the characteristics of the different sensors and connected equipment, see Section 2.

1.12. External signal wiring

A detailed description of all connection including signal wiring to and from the sniffer is available in Section 2. The Sniffer sensor is connected to the aircraft navigation instrumentation (Garmin GTN-650) using the Arinc protocol information on wind and positioning is provided to the Sniffer sensor.

The sniffer sensor system is a network based system. The means that all sensor data is gathered on the internal LOG-PC and made available for different IGPS software installations on client stations. The client stations are connected with the sniffer sensor via 2 Ethernet connections. 2 clients are used in the aircraft. One on the Mission Management Unit from Optimare on a Virtual Machine and one is connected to a wireless docking station (Lenovo WiGig Dock) that can be used in combination with the Lenovo Thinkpad portable computer (T460). The available IP addresses for client stations to connect to the sniffer sensor are available in Table 1, the subnet mask is 255.255.255.1.

Table 15 IP addresses for external connection to the sniffer sensor

IP addresses	User
192.168.1.230 -239	available
192.168.1.240	Console via VM
192.168.1.241	PC Ward via Thunderbolt
192.168.1.242	PC Kobe via Thunderbolt
192.168.1.243	PC Annelore via Thunderbolt
192.168.1.244	PC Benjamin via Thunderbolt
192.168.1.245	PC Ward via cable
192.168.1.246	PC Kobe via cable
192.168.1.247	PC Annelore via cable
192.168.1.249	PC Benjamin via cable

1.12.1 Operator laptop client stations

3 Lenovo T460 stations have been acquired to be used during sniffer flight. To enable the connection from the Laptop to the sniffer sensor the firewall settings have been adjusted (see Section 2).

1.12.2 MMU client station

The MMU is the main console in the aircraft used for the Medusa system. The MMU runs on a tailored Open Suse Linux Platform and is therefore not suited for the installation of the IGPS software. A Virtual Machine (VM Player) with a Windows XP installation is installed on the MMU to allow to run IGPS on the console, see Section 2 for the correct VM configuration.

The IGPS software is installed on the "C:" drive of this VM XP distribution. The firewall has been deactivated for the IGPS software. TeamViewer V12 has been installed on the VM to enable a remote desktop connection to the MUMM_LOG_PC. To allow sharing of folders with the console the shared folders must be activated in the Virtual Machine Settings and VMWare tools must be installed.

Note: Because of an IP address conflict with the Sniffer, the WiFi connection can currently not be used together with the sniffer sensor (network adapter for WiFi must be disabled when operating the sniffer), in case the FLIR camera is required the sniffer network adapter must be disabled first After connecting the FLIR camera, the sniffer network adapter can be re-enabled.

CHAPTER 2. MEASUREMENT UNCERTAINTY

2.1. Measurement quality

To assess a good quality measurement, the following requirements have to be met:

- plume can successfully be linked to a ship;
- response times of the SO_2 and CO_2 gas sensors are comparable;
- plume sampling time is sufficient;
- a good signal to noise ratio (SNR);
- no interference from land pollution or other sources.

2.1.1 Successful linking of plumes to ships

In the cases when ships are not emitting an AIS signal (e.g., military vessels) or when ships are sailing very close to each other with the same course and speed, it could be challenging to link a vessel to a plume. In some cases when vessels are crossing each other, plumes can be mixed. In those cases it is recommended not to conduct any measurements to avoid cross-linking of ships.

2.1.2 Response times (T90)

To assess the response times for the SO_2, CO_2 and NO_x gas sensors the T90 time can be calculated using the T90.xls file.

SOP 3.9. To compile the raw data

1. Conduct a software calibration (see Section 2)
2. Extract the data of the concerned log file (see 1.8 Analysis of LOG files using AIS Extract)
    a. Import the log file
    b. Open "Calculation T90.xls" file
    c. 05-FluxSense_Sniffer\0. QMS\3. SNIFFER DM\Data analysis\T90
    d. Open Import sheet
    e. Go to Data>Get Data>Legacy Wizards>TXT (legacy)
    f. Select EXTR-SO2.TXT, EXTR-LICRO7200.TXT or EXTR-Serinus40.TXT
    g. Use comma "," as separator
    h. Select finish
3. Copy the gas and time concentration to selection sheet
    a. For CO2
        - column AX will give the CO_2 in ppm
        - Colmun A will give the time of the sniffer (per second), column L will give the sensor time up to 0.1 sec for T90 calculations use column L
    b. for SO2
        - column F will give the SO_2 in ppb
        - Colmun A will give the time of the sniffer (per second)
    c. for NOx
        - column D will give the NO in ppt in scientific values
        - column J will give the NOx in ppt in scientific values
        - Column A will give the time of the sniffer (per second)

SOP 3.10. To transform the NOx data:

1. Select the columns D and J and click ctrl+h, write '= and select replace all
2. Split data, use "+" as separator and copy to a new column
3. Split data use "-" as separator
4. Create a new column that either contains the negative values (add -) or positive values for the exponents
5. Combine the value for the measurement with the exponent, devide by 1000 to arrive to the concentration in ppb

Note: excel templates exist for the automatic import of extracted files for NOx, CO2 and SO2 under T90 folder

SOP 3.11. To import the data in T90 file

1. Select data
    - **a.** With the selection graph, the correct start and end of the concentration peaks can be found
    - **b.** Up to 10 peaks can be calculated at once
    - **c.** Keep minimum 30 measurements before and after the concentration difference(s).
    - **d.** Delete the additional data
2. Go to T90 sheet, T90 times for upper and lower peaks are calculated automatically. A linear T90 is calculated automatically, for non-linear T90 calculation (interpolation between points or by fitting on S-curve) and interpretation a more detailed analysis is required, and should only be done by experienced data scientists
3. The UP and DOWN sheets provide graphs to interpret the linear and non-linear T90 times

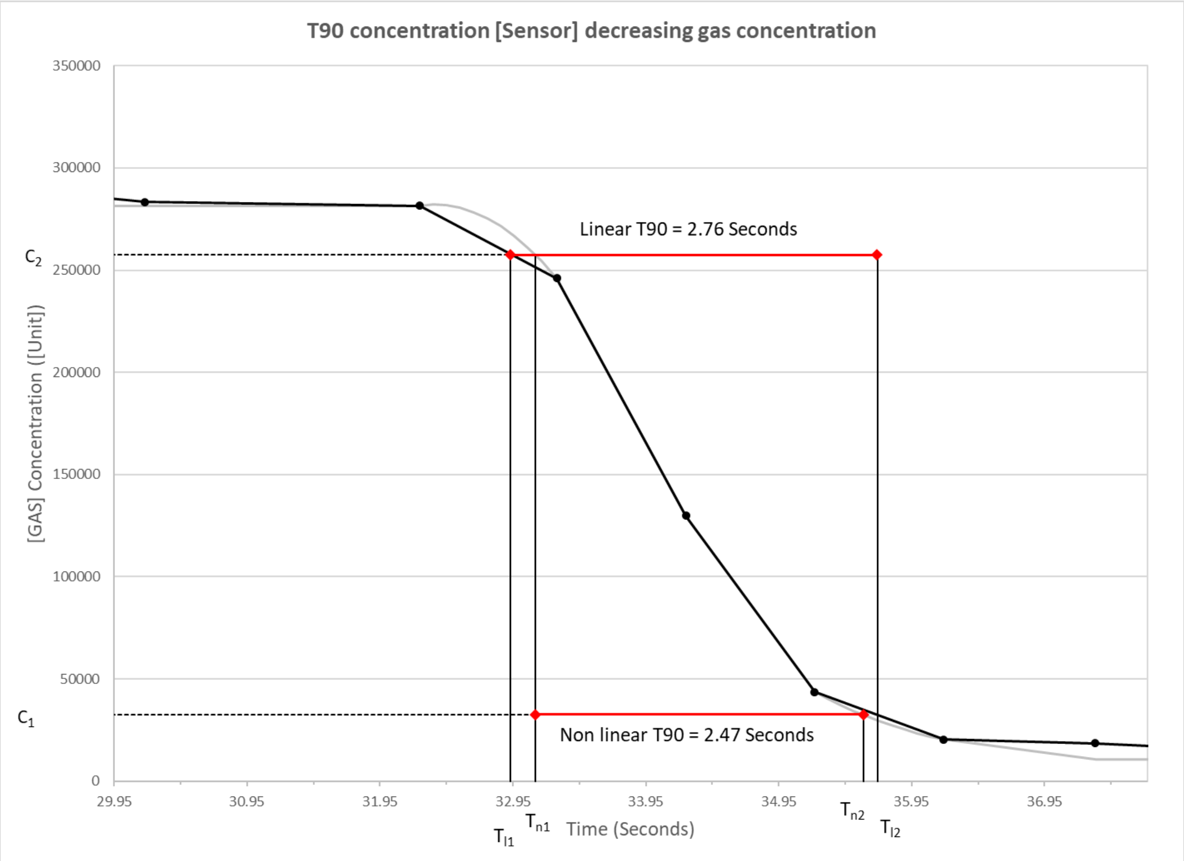


Figure 141 Automatic calculated T90 response time (this example is for decreasing gas concentration

The response time for the three sensors should be the comparable or SO_2 and NOx should be slightly slower than CO_2. (for 2019: T90 of SO_2: 3.52 sec and T90 of CO_2: 2.87 sec were sufficient).

2.1.3 Plume sampling time

To calculate the plume sampling time, the Emissiondata_xxx.TXT can be used, in this file the start and end of each plume is available.

SOP 3.12. To calculate plume sampling time

1. Import data using the IMPORT.XLSM file (See xxx)
2. Go to "Emissions" sheet and copy paste the relevant data (or all data) in a blanco sheet
3. Find plume sampling time
    a. Start time = tEndLeftBaseline
    b. End time = tStartRightBaseline
    c. In a new Colum create a difference between start and end time

The plume sampling time is sufficient when this is half the T90 time, in 2019 this was on average 7-8 seconds.

2.1.4 Noise

Noise is the variation in the gas concentration which is not a result from the measurement of plumes (signal). The noise factor is often expressed as the signal to noise ratio.

$$SNR = \frac{A_{plm}}{A_{bkg}}$$

SOP 3.13. To calculate the A_{bkg}

1. Extract a set of log files (see 1.8 Analysis of LOG files using AIS Extract)
    a. Go to Data>Get Data>Legacy Wizards>TXT (legacy)
    b. Select EXTR-SO2.TXT or EXTR-LICRO7200.TXT
    c. Use comma "," as separator
    d. Select finish
2. Copy the gas and time concentration to selection sheet
    a. For CO2
        - column AX will give the CO2 in ppm
        - Colmun A will give the time of the sniffer (per second), column L will give the sensor time up to 0.1 sec
    b. for SO2
        - column F will give the SO2 in ppb
        - Colmun A will give the time of the sniffer (per second)
    c. for NOx
        - column D will give the NO in ppt in scientific values
        - column J will give the NOx in ppt in scientific values
        - Colmun A will give the time of the sniffer (per second)
3. To transform the NOx data follow the steps
    a. Select the columns D and J and click ctrl+h, write '= and select replace all
    b. Split data, use "+" as separator and copy to a new column
    c. Split data use "-" as separator

d. Create a new column that either contains the negative values (add -) or positive values for the exponents
e. Combine the value for the measurement with the exponent, devide by 1000 to arrive to the concentration in ppb

Note: excel templates exist for the automatic import of extracted files for NOx, CO2 and SO2 under T90 fold

SOP 3.14. To calculate A_{plm}

1. Select a dataset with stable background (over sea) of minimum 60 measurements
2. Calculated the Standard deviation ("STDEV()")

To guarantee a sufficient quality, only plumes with a minimum SNR of 15 are deemed acceptable, for SO2 a lower SNR of 10 can be used as for non-compliant ships always 2 measurements are made. With the A_{bkg} the minimum A_{plm} can be calculated for an SNR of 15 or 10. Based on the data from 2019 a sufficient SNR as achieved from **5ppb CO_2**, for non-compliant ships a minimum peak of **3ppm SO2** is required. (See Section 1)

In some occasions background conditions may be unstable, resulting in more noise. When these conditions are observed and the quality of the measurements cannot be ensured, the Marpol Annex VI mission type should be interrupted and the operators should switch to a general pollution control mission. Main reasons for these unstable background are e.g. land based pollution (close to shore) and smog due to inversion layers. (See Section 1)

The described minimum peak height provide some guidance but ultimately the operators should rely on their experience to assess if the quality of the measurement is acceptable or not, when in doubt it is best to seize the operations.

2.2. Measurement uncertainty FSC

Initially limited information was available on the measurement uncertainty, which was estimated at 50% FSC (Berg et al., 2010). The uncertainty of the Belgian FSC measurements (U) can be defined as a combination of the measurement bias (b) and the standard deviation (u_{tot}):

$$U = |b| + \sigma . u_{tot} \tag{11}$$

To calculate the measurement bias, the median of the airborne emission measurements should be (preferably annually) compared to the median of a set of 30 random fuel sample analysis taken by PSC in a certified laboratory (uncertainty <0.01%). This will give an approximate bias (0.018 +/- 0.005 % FSC).

Note: The bias is actually larger (ca -0.07), but the NO cross sensitivity (+0.05) is partially correcting this bias.

The standard deviation can be calculated based on the intra-assay coefficient of variability and the sum of all additional supplementary uncertainty factors ($u_{sup,i}$). See Table 16 for an overview of these supplementary uncertainty factors.

$$u_{tot} = \sqrt{(CV_{RW})^2 + \sum \left(u_{sup,i}\right)^2} \tag{12}$$

$$CV_{RW} = \frac{1}{\sqrt{2}}\sqrt{\frac{\sum_{i=1}^{n}\left(\frac{x_{i1}-x_{i2}}{0.5(x_{i1}+x_{i2})}\right)^2}{n}} \times 100(\%) \quad (13)$$

The CV_{RW} is calculated on a set of repeated measurements (ships that have been measured twice). The CV_{RW} should be annually updated based on the new data. The CV_{RW} are calculated for 3 different ranges of FSC values. The supplementary uncertainty factors include all additional uncertainty factors. Some were calculated based on the observed values (see. drift values) others, like sensor uncertainty, were based on description from literature or from the sensor manual. In those cases, the used CI is 95%.

The supplementary uncertainty factors are listed in Table 16. The uncertainties of the span gasses should be updated on annual basis. With the bias and total uncertainty values, the combined uncertainty can be calculated for the three FSC levels.

Table 16. Supplementary uncertainty factors and the combined supplementary standard uncertainty.

Supplementary uncertainties	Max
SO_2 span gas drift (3 months)	2.77%
SO_2 span gas concentration*	0.20%
CO_2 span gas drift (6 months)	0.92%
CO_2 span gas concentration*	0.05%
Measurement accuracy SO_2 sensor	0.40%
Measurement accuracy CO_2 sensor	0.05%
Error on FSC correction (offset reference)	2.35%
Error on FSC correction (offset measured)	2.17%
Error on FSC correction (Slope reference)	2.79%
Error on FSC correction (Slope measured)	4.26%
Uncertainty molar mass S	2.49E-06
Uncertainty molar mass O	1.88E-05
Uncertainty molar mass C	0.01%
Uncertainty molar mass N	2.49E-06
Uncertainty C content in marine fuel	0.83%
Combined supplementary standard uncertainty $\sum u_i^2$	3.17%

An additional reason for uncertainty is the sensitivity of the SO_2 sensor to VOCs from marine lubricants in OGV emissions. In standard SO_2 analyzers VOCs are filtered out with a hydrocarbon kicker. This kicker restricts the airflow to 0.8 l/min, much lower than the required 6 l/min, and is hence not used in the airborne sniffer system. As a result, in some cases (less than 1 on 20) the SO_2 concentration may not drop back to the background levels together with the CO_2 concentration. This is probably due to an adhesive effect of the VOCs in the measurement chamber of the SO_2 sensor. In those cases the SO_2 level should be cut off together with the CO_2 to avoid an overestimation of the FSC.

2.2.1 Updating FSC uncertainty factors

On annual basis the new uncertainty factors should be calculated to refine the uncertainty calculations.

SOP 3.15. To update the uncertainty factors

1. Open de Accuracy.xls file

05-Instrumentation 0. QMS\3. SNIFFER DM\Data analysis\Acuracy analysis\Accuracy.xls

2. Calculate new bias
   a. Calculate median from 30 Fuel samples (via function: "median()")
   b. Calculated the median from the FSC values from the corresponding period
   c. Copy paste the values in the "Bias" sheet in the Accuracy.xls file
   d. The bias will be calculated and should be copied to the "uncertainty FSC" sheet
3. Open the updated longterm dataset Sniffer long term results 2015-xxx (see xx)
4. 05-Instrumentation\05-FluxSense_Sniffer\0. QMS\3. SNIFFER DM\Data analysis\Belgian Sniffer Campaign 2021
5. Calculate the updated CV_{RW} per alert level
   a. Filter data on colour flag (green+yellow)
   b. Filter data that has 2 measurements (deselect "na" for FSC-2)
   c. Copy paste the filtered data to the correct sheet (man-man <0.2")
   d. Repeat the same with the other colour flags
      - Orange: "man-man 0.2-0.4"
      - Red: "man-man>0.4"
6. Copy paste the updated CVRW to the "uncertainty FSC" sheet in Accuracy.xls file
7. Calculate the supplementary uncertainty factors Go to SQMS follow up.xls
   a. Go to GAS CAL sheet
   b. Calculated the average drift of the SO2 gas mixtures used that year (select values and average is displayed in the bottom)
   c. Fill in this value in the "uncertainty FSC" sheet in Accuracy.xls file (in "min" column)
   d. Do the same for CO2
8. Copy new Bias and FSC uncertainty factors to 0. QMS\3. SNIFFER DM\IMPORT IGPS DATA\Import.xlsm uncertainty sheet (hidden)
9. Save import file

2.3. Measurement uncertainty NOx

Similarly as for FSC the total NOx uncertainty measurement (U) can be described as a combination of the measurement bias (b) and the standard deviation (u_{tot}):

$$U = |b| + \sigma . u_{tot} \tag{14}$$

In contrast to the FSC, where fuel samples from port inspections were used to calculate the, no reference data is available for NO_x. Nevertheless it can be assumed that there is a negative systematic error for several reasons. The first is the difference between indicated power of the main engine, which is requested through radio communication and the brake power which is used in the NO_x technical code. The brake power is measured at the crankshaft using a brake dynamometer. For conformity and simplification the indicated power is requested when contacting an OGV. As the indicated power is always higher due to friction losses of the shaft and auxiliary systems connected with the main engine. The ratio between indicated power and brake power is expressed as mechanical efficiency (N_m). This efficiency is in the order of magnitude of 95% at full power but can be as low as 75% at rated speed. The use of the indicated power instead of the brake power means an overrating of the power output in the SFC formula and therefore will result in an underestimation of the SFC and NO_x emissions by ca. 15%.

The next factor is the temperature and a humidity correction. The NO_x Technical Code describes that a correction should be applied for the air intake temperature and humidity.

$$k_{hd} = \frac{1}{1 - 0.0182 \times (H_a - 10.71) + 0.0045 \times (T_a - 298)} \tag{15}$$

In the Belgian part of the North Sea the annual average temperature is 11.9°C, the annual average maximum temperature is 14.5°C with an average humidity of 5.6 g/kg dry air. The corresponding combined average negative correction is 3.4% with a range between 2-4% (see Figure S.10).

The last factor is the impact from auxiliary engines and generators. These are generally 4 stroke engines with a higher ERS and have therefore lower emission limits. As only OGVs that are en route are measured, the impact of the exhausts of these engines on the emission measurements of the main engine is limited. Nevertheless due to a dilution effect, main engine exhaust with higher NO_x/CO_2 ratios might be mixed with lower auxiliary engine exhaust with lower NO_x/CO_2 ratios and thus creating a negative bias. The part of the auxiliary exhausts in the total OGV exhaust is impossible to determine in flight, nevertheless auxiliary engine(s) can take up to 10-15% of the used fuel on the total journey. This amount can be even higher when the ship is sailing at very low speeds (DNV-GL, 2015; Heywood, 2018). Auxiliary engine emission limit correspond to circa 58-64% of the limit of main engines (ERS ≥ 1000 rpm), the negative bias is therefore estimated to be in the order of magnitude of 4-6%. The combined negative systematic error is therefore estimated to be 15-25%. The NO_x Technical Code provides a margin of 10% to account for the simplified measurement methods as described in Chapter 6 and an additional 10% allowance for the use of non-residual marine (non-RM) graded fuel (ISO8217:2005) such as distillates like Marine Gas Oil (MGO), although the combined allowance should not exceed 15%. For this reason, the negative systematic error was not used to correct the measurement data for reporting to PSC, as this was mostly eliminated by the 15% allowance.

The second part of the uncertainty is described by the standard deviation of the measurements. When comparing the results of repeated measurements, it was observed that in most cases the measurement data correlated strongly (R^2 =0.84). Furthermore no strong relative effect is observed on the difference between both values, although the difference between two measurements is clearly smaller for lower NO_x values than for higher measurement values.

The standard deviation u_{tot} can be calculated based on the intra reproducibility coefficient CV_{RW} and the sum of all additional supplementary uncertainty factors (u_{sup}).

$$u_{tot} = \sqrt{(CV_{RW})^2 + \sum \left(u_{sup,i}\right)^2} \tag{16}$$

$$CV_{RW} = \frac{1}{\sqrt{2}} \sqrt{\frac{\sum_{i=1}^{n} \left(\frac{x_{i1} - x_{i2}}{0.5(x_{i1} + x_{i2})}\right)^2}{n}} \times 100(\%) \tag{17}$$

To calculate the standard deviation, 3 intra reproducibility coefficients have been calculated for 3 different ranges of NO_x emission values: 0-10 g NO_x/kWh, 10-20 g NO_x/kWh and >20 g NO_x/kWh. The CV_{RW} values are displayed in Table S.2.

The supplementary uncertainty factors are listed in Table S.1. For the reported indicated power an uncertainty of 6.8% was used and for the provided fuel consumption 10% was, although this does not include an uncertainty due to human errors during reporting. From the 43 OGVs that were contacted, 16% provided unreliable data, for those OGVs the standard SFOC of 200 g fuel/kWh was used. With the bias and total uncertainty values, the combined uncertainty was calculated for the three NO_x emission levels.

Table 17 Supplementary uncertainty factors NOx

Supplementary uncertainties	Max
NO_x span gas drift (3 months)	1.97%
NO_x span gas concentration*	3.00%
CO_2 span gas drift (6 months)	1.44%
CO_2 span gas concentration*	2.00%
Measurement accuracy NO_x sensor	0.50%
Measurement accuracy CO_2 sensor	1.00%
Uncertainty molar mass N	6.07E-05
Uncertainty molar mass O	1.88E-05
Uncertainty molar mass C	0.02%
Uncertainty C content in marine fuel	1.34%
Uncertainty Indicated power	6.8%
Uncertainty fuel consumption	10.00%
Combined supplementary standard uncertainty	12.97%

** According to gas analysis certificate*

2.3.1 Updating NOx uncertainty factors

Also for NOx the uncertainty should be recalculated on annual basis.

SOP 3.16. To calculated the new uncertainty factors

1. Open de Accuracy.xls file
2. 05-Instrumentation 0. QMS\3. SNIFFER DM\Data analysis\Acuracy analysis\Accuracy.xls
3. Open the updated longterm dataset Sniffer long term results 2015-xxx (see xx)
4. 05-Instrumentation\05-FluxSense_Sniffer\0. QMS\3. SNIFFER DM\Data analysis\Belgian Sniffer Campaign 2021
5. Calculate the updated CVRW per alert level
    a. Filter data on per emissionlevel (smaller than 10 g NOx/Kwh)
    b. Filter data that has 2 measurements (deselect “na” for FSC-2)
    c. Copy paste the filtered data to the correct sheet (man-man <0.2”)
    d. Repeat the same with the other levels
        - 10-20 g NOx/kWh
        - >0.4 g NOx/kWh
6. Copy paste the updated CVRW values to the “uncertainty NOx” sheet in Accuracy.xls file
7. Calculate the supplementary uncertainty factors Go to SQMS follow up.xls
    a. Go to GAS CAL sheet
    b. Calculated the average drift of the NO2 gas mixtures used that year (select values and average is displayed in the bottom)
    c. Fill in this value in the “uncertainty NOx” sheet in Accuracy.xls file (in “min” column)
    d. Do the same for CO2
8. Copy new NOx uncertainty factors to 0. QMS\3. SNIFFER DM\IMPORT IGPS DATA\Import.xlsm uncertainty sheet (hidden)
9. Save import file

CHAPTER 3. THREHOLDS FOR REPORTING

3.1. FSC threshold calculation

Three alert levels (colors) are created. For each color flag an operational reporting threshold (T_{OPS}) is defined. The yellow flag represents the lowest alert level of 0.15% FSC. The orange flag indicates a medium alert level of 0.2% FSC and red flags indicates a high non-compliance alert, set at 0.4% FSC. The actual threshold (T_a) is defined as the FSC for which the difference with the combined measurement uncertainty exceeds a pre-defined sulfur limit (S).

$$S\ (\%FSC) = T_a(1 - U) \tag{14}$$

$$T_a = \frac{S}{1 - U} \tag{15}$$

Different CIs are used per alert level. For the yellow color flag a CI of 68% is used (σ = 1), for the orange color flag a CI of 95% (σ = 1.96) is used, for highest alert level, a CI of 99% is used (σ = 2.576). In addition, different Sulfur limits (S) are used to reflect on the level of PSC follow-up as well. For the yellow flag, a sulfur limit of 0.10% is used. This means that for a yellow alert there is a 68% probability that the FSC value of the OGV is more than 0.10% FSC. For the orange flag, a sulfur limit of 0.11% FSC is used, as this is the limit that can be confirmed by laboratory fuel sampling analysis. This means that an orange alert has an FSC that is more than 0.11% FSC with a CI of 95%. For the red flags, the sulfur limit is set at 0.15% FSC. For red alerts the FSC is more than 0.15% FSC with a CI of 99%. The actual resulting measurement thresholds per color flag are displayed inTable 18. The actual thresholds should be lower than the operational thresholds (T_{OPS}) for an additional margin of error.

3.2. Updating FSC Threholds

The thresholds have to be checked on annual basis (with the updated uncertainty factors and bias), in case the actual threshold exceeds the operational threshold, the threshold should be corrected. In case the actual thresholds would be much lower than the operational threshold, the operational thresholds might be lowered, this should always be approved by FOD Mobility.

To update the Thresholds it suffices to calculate the updated uncertainty factors and bias (See 1.11, the updated threshold are available on the bottom of the sheet and should be when changed updated in the “Threholds and Bias.xls” file on der C:\\IGPS folder

Table 18 Alert flag thresholds 2022 (t values were used in stead of σ due to n<30)

Color flag	t	U	CI	Sulfur limit	T
Yellow	0.86	22%	60%	0.10%	0.13%
Orange	2.179	38%	95%	0.11%	0.19%
Red	2.528	48%	99%	0.15%	0.28%

Table 19 Thresholds used in flight (in Thresholds and Bias.xls on C:\\IGPS folder)

Thresholds		CI
Yellow	0.13	60%
Orange	0.2	95%
Red	0.3	99%

3.3. NOX threshold calculation

As for FSC, a color flag system was composed that incorporates the measurement uncertainty, but also reflects on the level of non-compliance. The compliance threshold (T) was defined as the NO_x emission measurement value from which the OGV is considered to be non-compliant and would therefore be alerted to PSC authorities. The Threshold is reached as soon as the NO_x emission minus the measurement uncertainty is higher than the Tier limit (L) plus the NTE.

$$L_{Tier_i} + NTE = T - U_T \quad (18)$$

$$T = \frac{L_{Tier_i} + NTE}{1 - \sigma \times u_{to}} \times (1 + b) \quad (19)$$

For operational use the thresholds are further rounded up to 5 g NO_x/kWh for Tier I and Tier II and to 1 g NO_x /kWh for Tier III. Thus creating operational thresholds, that are convenient for the operators to memorize and apply in flight

3.3.1 Tier I and Tier II

The lowest alert level, the yellow flag color, uses a 68% confidence interval (CI) and a not to exceed limit (NTE) of 15%, corresponding to the 15% margin of the NO_x Technical Code. The medium alert level, the orange flag color, uses a 95% CI with a NTE limit of 20% for Tier I. The red flag is used for high non-compliance alerts, with a CI of 99% and a NTE limit of 50%. The NTE levels for the orange and red flags are higher to take into account a tolerance level for the weighting factors.

3.3.2 Tier III

As no data yet exists for Tier III, the uncertainty for this measurement range could not yet be calculated. Nevertheless it can be assumed that this would be comparable to the uncertainty of Tier I and Tier II. For the Yellow flag a 50% NTE limit was used corresponding to the NTE limit of the NO_x Technical Code. For the Orange and Red flag a NTE of 60% and respectively 65% was used to incorporate an additional tolerance due to the low emission limit and unknown uncertainty.

Table 20 Threholds and uncertainty for different Tier levels

Tier	L_{Tier}	Color flag	NTE	σ	T	T_{ops}
		Yellow	15%	1	21.2	25
*Tier I**	17	*Orange*	20%	1.96	31.8	35
		Red	50%	2.576	53.2	55
		Yellow	15%	1	17.9	20
Tier II	14.4	*Orange*	20%	1.96	26.9	30
		Red	50%	2.576	45.0	45
		Yellow	50%	1	5.4	6
Tier III	3.4	*Orange*	60%	1.96	7.5	8
		Red	65%	2.576	8.9	9

3.4. NOX threshold update

The determination of the initial thresholds was based on test measurements from 2020. The thresholds have to be checked on annual basis (with the updated uncertainty factors), in case the actual threshold exceeds the operational threshold, the threshold should be corrected. In case the actual thresholds would be much lower than the operational threshold, the operational thresholds might be lowered, this should always be communication with FOD Mobility.

To update the Thresholds it suffices to calculate the updated uncertainty factors and bias (See 1.11, the updated threshold are available on the bottom of the sheet and should be when changed updated in the "Threholds and Bias.xls" file on der C:\\IGPS folder.

Table 21. Updated Thresholds for ERS < 500 RPM

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (>2021)	Tier I+II	Tier III	CI
Limit (130xRPM)	17	14.4	3.4	NTE (BE)	NTE (IMO)	
Yellow	25	20	7	15%	50%	68%
Orange	35	30	9	20%	60%	95%
Red	55	45	12	50%	65%	99%

Table 22 Updated Thresholds for ERS > 500 RPM

Threholds	Tier I ('01-'10)	Tier II ('11-'20)	Tier III (>2021)	Tier I+II	Tier III	CI
Limit (500xRPM)	13	10.5	2.6	NTE (BE)	NTE (IMO)	
Yellow	20	15	5	10%	50%	68%
Orange	25	20	6	20%	50%	95%
Red	45	35	7	50%	50%	99%

CHAPTER 4. REPORTING OF NON-COMPLIANCE DATA

This chapters describes the specific reporting procedures for the reporting of non-compliant ships. Chapter 5 describes the reporting procedures for the reporting of all compliance data in bulk, for reporting to Thetis-EU and third parties, hence the reporting for all compliance data also includes the reporting of non-compliance data.

The operational procedures for reporting of non-compliant ships follow the general operational reporting procedures for other violations, these procedures are described under Chapter 3 and Chapter 4 of the OPS manual and can be found on 04-OPS-Manual\OPSMANUAL Draft july19.

It is crucial to provide fast and accurate reporting for non-compliant ships as the airborne monitoring can only be used for targeting ship inspections in port. All crucial steps for the gathering of reliable and high quality data are provided in Section 1. It is important that all quality requirements are fulfilled (see 2.1 Measurement quality) or in case not all requirements are fulfilled that these are documented during the reporting of the non-compliant vessels.

Example in case only one measurement could be made, the alert can still be reported but it should be specifically mentioned in the report.

4.1. Flight report creation

The standard flight report should be used for the reporting of non-compliant ships, see **Annex C - Flight report** for an example of such a flight report for Marpol Annex VI

4.1.1 Data collection

After a non-compliant ship is observed and 2 measurements were made , the measurement data (FSC values, color flag, country, shipname) should be written down on the flight log and the event data should be collected in MEDUSA. Once the data is collected in the event management tool, a flight report needs to be created for every single observed potential violation:

SOP 3.17. To create the pollution event

1. Identify Colour Flag and country in which waters the detection was made
2. Make event on console +
    a. Open AIS INFO (GUI>>ECS>>AIS Info)
    b. Click on the target
    c. Select “Create Target”
3. Select event
    a. Got to event management (GUI>>Control>>Event Management)
    b. Scroll through event list and look for the correct event (last event is displayed on top)
    c. If necessary click on “reset”
4. In the right part of the window in the observation type drop down list select “Pollution”
5. Copy paste comments to further remarks
    a. Cut-paste AIS ship info of polluter to ‘remarks’ in the event manager, keep relevant info:
        - Shipname,
        - IMO number,

- MMSI number,
- Destinations,
- ETA,
- Shiptype,
- Dimensions,
- SOG, COG

b. Check next Port of Call
c. Add 2 FSC values in "Further Remarks", add Colour Flag and "confirmed by second measurement"

6. Fill in polluter name in "polluter observed"
7. For substance, type "SO_2"

SOP 3.18. To create a flight report

1. Generate Flight Report with the MEDUSA Analysis tool
   a. GUI>>Control>>Analysis
   b. Select flight nr
   c. Go to Start>>Generate flight nr
   d. Deselect all events and pictures
   e. Select the correct event
   f. Select "Generate report"
2. Open the report on the Mission folder of the corresponding flight
   a. Mission data is stored per flight number on the MSU
   b. Per mission a set of folders is created, the flight reports are stored under "Report" folder
   c. If multiple reports are generated per flight they will receive an sequence number
3. Open the flight report with calc
4. Following items need to be checked or modified in the report
   a. Use Scenario 37
   b. Check recipient list
   c. Add SIOB email for ships going to SECA ports (others than NL/BE)
   d. Make sure PSC (ILT and FOD Mobility are added)
   e. Add NFP of affected Coastal State (if measured in FR, NL or UK waters)
   f. Add concentration in quantity (add unit % (FSC)

4.2. Communication chain reporting

The flight report should only be send to the MIK. MIK will be responsible for forwarding the flight report to the legal competent authorities. Use preferably the email provider on the console for emailing the flight reports to the MIK (Thunderbird). Special templates have been created for every operator. These templates can be found under the local folders.

SOP 3.19. To send a flight reports to MIK:

1. Open thunderbird (GUI>>Control>>Email)
2. Go to templates under local folder
3. Select your personal operator folder (acronym)
4. Select and double click on the "Flight report XXX Marpol Annex VI XXX Flag XX" email
5. Modify the title
   a. Add Flight number

   b. Add Colour flag
   c. Add Country
   d. Example: Flight report 19148 Marpol Annex VI Yellow Flag FR
6. Add the flight number on XXXs in the email body and send email

```
Dear,

In attachment you can find the Belgian Coast Guard Flight Report of flight
XXX.

This report concerns the observation of a possible MARPOL Annex VI
violation.

MVG
```

Figure 142 Email for reporting Marpol Annex VI violations to MIK

4.2.1 Identities

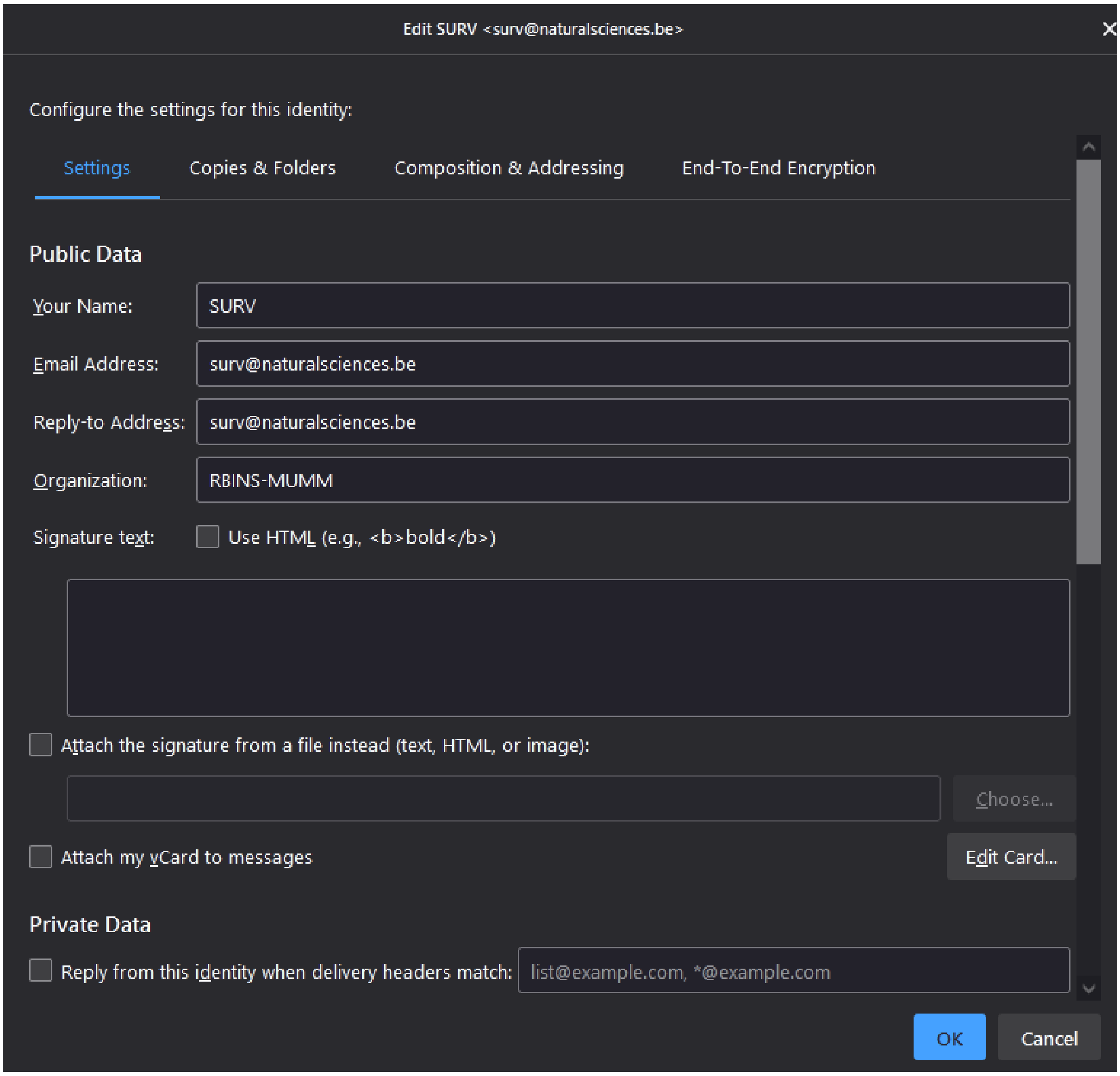
The Sniffer flight report templates have been created with individual identities per operator. This was done to optimise the communication. As the surv email address is only used as alias it is not possible to add this account to thunderbird, an additional email address was created OO-MMM@naturalsciences.be this email address is for internal use only and should never be used for reporting to external partners. By using identities, it is possible to assign another email address as outgoing email address.

The MIK operator will not only receive all emails as if they were send from the Surv@naturalsciences.be email address but when replying to a flight report not only SURV will be contacted but also the individual email address of the reporting operator will be contacted.

SOP 3.20. To create or modify an identity

1. Go to the account settings of the surv email account (right click on oo-mmm@naturalsciences.be 365)
2. Go to “Manage Identities”
3. A window will appear
   a. Add: to add new identity
   b. Edit: to edit the settings of an existing identity
      - Select identity that needs to be modifed
      - Click edit
4. A window with alle settings will appear following items can be personilised per identity
   a. Name
   b. Email address: surv@naturalsciences.be
   c. Reply to address: surv@naturalsciences.be + optional other addresses
   d. Signature text: eg.:

      --
      Ward Van Roy
      SURV team
      Royal Belgian Institute of Natural Sciences Scientific Service MUMM Rue Vautier 29
      1000 Brussels
      surv@naturalsciences.be
      ward.vanroy@naturalsciences.be
      Mobile: 0032 476 94 04 08


Edit SURV <surv@naturalsciences.be>
Configure the settings for this identity:
Settings
Copies & Folders
Composition & Addressing
End-To-End Encryption
Public Data
Your Name:
SURV
Email Address:
surv@naturalsciences.be
Reply-to Address:
surv@naturalsciences.be
Organization:
RBINS-MUMM
Signature text:
Use HTML (e.g., bold)
Attach the signature from a file instead (text, HTML, or image):
Choose...
Attach my vCard to messages
Edit Card...
Private Data
Reply from this identity when delivery headers match:
list@example.com, *@example.com
OK
Cancel

CHAPTER 5. REPORTING OF COMPLIANCE DATA

5.1. Reporting to PSC

The sniffer measurement results of non-compliant vessels have to be reported to PSC and the vessels will then be marked in the Thetis-EU database. Therefore the aerial monitoring results on non-compliant vessels should be reported in near real time. For a non-compliant vessel, this means that reporting time is limited to 15 min after landing in order to provide sufficient time for the planning and prioritisation of port inspections. The flight report is send to the national 24/7 coastguard station (MIK), who forwards the flight report to PSC. Measurement results of both non-compliant as compliant vessels are also shared throughout Thetis-EU, this data-export and upload process is largely automated, but some data still needs to be validated manually.

Table 2 PSC-Communication matrix

	Compliant	Non Compliance
Reporting Time	<1hr after flight	Near real time (<15 min after landing)
Reporting Means	Thetis-EU web database	Thetis-EU + Flight report

5.2. Import of ship monitoring data

After all sniffer measurements are done, but **before the sniffer is shut down** the emission file and log files from the MUMM LOG PC need to be backed-up by the laptop operator. After which the data can be imported for backup and sharing with Thetis-EU.

SOP 3.21. To backup flight data

1. Copy logs
   a. On laptop go to MUMM-LOG-PC on TeamViewer
   b. Go to C:/IGPS/TCP LOG
   c. Copy recent TCP logfiles (from same day)
   d. On Laptop go to seafile folder 0.QMS\Sniffer DM\Logs\YEAR
   e. Paste the files, in case error message pops up, select "Don't copy" + "do this for all other x files"
2. Copy the emission file
   a. On laptop go to MUMM-LOG-PC on TeamViewer
   b. Go to C:/IGPS
   c. Copy Emissionsdata_MUMM_LOG_PC.txt
   d. On laptop go to C:/IGPS/
   e. Paste the emission file, select "replace"

SOP 3.22. To import IGPS data

1. Open personal file "IMPORTV22_operatorinitials.xlsm" in "Seafile >> 11-Instrumentatie >> 05-Fluxsense_Sniffer >> SNIFFER DATA >> IMPORT IGPS DATA
2. Import the raw data
   a. The first button will import all data from the C:\IGPS directory
   b. The second button will allow you to import data from a dedicated directory (eg. IGPS POST FLIGHT)

3. Click third button "Calculate Results", the Results sheet will be opened,
4. Check if all ships are present
    a. If all ships are present continue with 5
    b. (if not close import and add measurements, see **5.2** and restart at 1)
5. Edit data in Results sheet
6. Delete double lines
7. Add the number of attempts
8. Check for unknown Keel Laying Years (e.g. use Thetis-EU or Marine traffic);
9. Check the colour flags for FSC
    a. Check if the sequence is correct for NO/NOx
    b. Check the sequence of the emissions measurements
    c. In case a ship has 2 different colour flags use lowest flag
    d. Ungroup the columns right from the emission measurement (blue numbers) change from 1,2,3 to 2,1,3 or accordingly
10. Check the colour flags for NOx
    a. Check the Gross Tonnage for TIER 0 ships with length <150m
    b. check the sequence of the emissions measurements, in case a ship has 2 different colour flags use lowest flag
    c. Ungroup the columns right from the emission measurement (blue numbers) change from 1,2,3 to 2,1,3 or accordingly
11. Recalculate sheet, and check if all adjustments are made correctly
12. Go back to "guidelines" and add start date (if different from the present day) add start/end times in case of multiple flights
13. Add flight number
14. Click apply filter
15. Check the Full data, ILT and EMSA sheets (sheets are read only)
16. Click on all 3 Export buttons
    a. Full data will be exported in the standard YEAR directory,
    b. ILT sheet will be exported in the EXTERN directory
    c. The EMSA file will be exported in the EMSA input files data directory)

Note: For violations check if after 15 min the EMSA file is moved from the "input files" directory to the "imported" directory and the alert is available on Thetis-EU

5.3. Missing data

IGPS present can be used to reload old mission data (from log files), a special IGPS Post flight folder has been installed on the C:\ and shared through seafile, this contains the same software and folders as the IGPS folder, but the advantage is that the data may be deleted. When it is observed during the import step that a ship is missing from the imported list this means that the second operator forgot to assign "LOW"/ "High" / "Not Detected" to the ship after measurements. In case the ship is available in the list but the measurements are missing the measurement needs to be redon

SOP 3.23. To reload flight log data

1. Copy Emissiondata_ODN_XXX.rbins.be.txt from C:\IGPS to C:\IGPS POST FLIGHT folder

2. Open IGPS POST FLIGHT and open LOG file (SNF>>Setting>>load data file>>Select LOG with flight hour)
3. Flight will be loaded (slow) to go faster to the correct time click on the SNF graph (look at timer)
4. When time is right, go to MAP to identify ship and when AC passes through ship plume go to SNF
5. Do measurement and assign measurement to correct ship
6. Data is now added to the emission data under the IGPS post flight folder and be either copied back to the IGPS folder or can be imported from the IGPS Post flight folder in the Import.xls file

SOP 3.24. To add missing ships

1. Identify the approximate time of the missing ship
2. Copy the sniffer file
    a. Go to C:\IGPS\ -Mail_Sniffer_SO2_Man_Meas.CSV
    b. Copy file to C:\IGPS Post Flight, select "Replace"
3. Open IGPS from the IGPS POST FLIGHT (AISPresent63.exe)
4. Load data
    a. Go to SNF>>Setting>>load data file
    b. Select LOG based on flight date and hour from 0.QMS\Sniffer DM\Logs\YEAR
5. Flight will be loaded (slow)
6. To go faster to the correct time click on the SNF graph (look at timer)
7. When time is about right, click cancel
8. Go to MAP and select ship ("LOW, HIGH, Not Detected")
9. Copy paste the sniffer file from C:\IGPS Post Flight back to C:\IGPS

SOP 3.25. To add missing measurements:

1. Identify the approximate time of the missing measurement
2. Copy the local emission file
    a. Go to C:\IGPS\Emissiondata_ODN_XXX.rbins.be.txt (xxx stands for the machine name)
    b. Copy file to C:\IGPS Post Flight, select "Replace"
3. Open IGPS from the IGPS POST FLIGHT (AISPresent63.exe)
4. Load data
    a. Go to SNF>>Setting>>load data file
    b. Select LOG based on flight date and hour from 0.QMS\Sniffer DM\Logs\YEAR
5. Flight will be loaded (slow)
6. To go faster to the correct time click on the SNF graph (look at timer)
7. When time is about right, click cancel
8. Go to MAP and wait until the ship is measured
9. Go to SNF and pause the data flow
10. Click on the CO2 window and conduct the measurement
11. Assign the measurement to the correct ship
12. Go to SNF and stop the pause
13. Close IGPS
14. Copy paste the emission file from C:\IGPS Post Flight back to C:\IGPS

SOP 3.26. To remove a measurement

1. Close all IGPS software

2. Open sniffer file (C:\IGPS\ -Mail_Sniffer_SO2_Man_Meas.CSV) in notepad
    a. Right click on file
    b. Select open with
    c. Select Notepad
3. Identify the line of the wrong ship :
    a. start scrolling from the bottom),
    b. ship names are at the end
4. Delete the line that corresponds to the wrong ship completely
5. Save the CSV file

SOP 3.27. When a measurement is connected to a wrong ship or needs to be deleted:

1. Close all IGPS software
2. Open emission file (C:\IGPS\Emissiondata_ODN_XXX.rbins.be.txt) in notepad
    a. Right click on file
    b. Select open with
    c. Select Notepad
3. Identify the line of the wrong measurement
    a. Start scrolling from the bottom)
    b. Ship names are at the end
    c. Identify the lines that start with “Name_Manual Plume”
4. Delete the line that corresponds to the wrong measurement
5. Save the text file

5.4. EMSA Thetis-EU export tool

All data that is stored in the EMSA folder with the correct format will automatically be uploaded to the Thetis-EU data base. The EMSA folder consists of following subfolders:

- Discarded: non imported files
- Imported: successfully imported files on Thetis-EU
- Inputfiles-data: this folder should be used to copy the EMSA sheet into (see previous section)
- Pending: this folder will contain files with errors that should be checked before they can be imported
- Reporting errors: this file contains all reported errors

A special database tool is created by MUMM, this database will in a first step import the data in a SQL database, in a second step the data will be streamed to the EMSA database.

5.4.1 Problems with import

In case the import is done successfully, no error mail will be send and the csv file will be replaced to the imported folder. In case the system encounters an error during the import an error mail is send to the oo-mmm@naturalsciences.be email address. The records concerning the error will be mentioned with a brief description of the error.

Following errors or commonly reported:

SOP 3.28. In case of invalid IMO number

1. No action required, this is a common error but does not interfere with the import of the data

SOP 3.29. In case of missing data or invalid data:

1. Message code: ['SULPHUR_ContentUncertainty_1=Na NOT VALID']
2. Open xxxx_Sniffer Flight.csv
3. Check which data is missing,
   a. For ship characteristics: go to Marine traffic and look for the correct data

For measurement data, in case measurement data is missing form the Full data sheet, the data should first be recollected (see 5.1)

SOP 3.30. For missing uncertainty in EMSA file

1. Look for comparable measurement in FSC
2. Copy paste the value from another record (e.g. uncertainty for a value of 0.08 is comparable to uncertainty of value of 0.09)

SOP 3.31. For missing Measurement ID in EMSA file

1. Copy paste the ID of the last measurement
   a. Add one number to the last value (e.g. BE20191008ODIN-RBINSOO-MMMR4)
2. For other missing data
   a. Copy paste data from record before the missing record or interpolate for time

SOP 3.32. In case of wrong name or format in EMSA file (wile not using macro)

1. In this case the xxxx_Sniffer Flight.csv was not saved correctly, in this case nor error mail will be send and the file will remain in the input folder. This often happens when in stead of the EMSA sheet, the ILT sheet was exported to the EMSA directory
2. The incorrect CSV should be deleted
3. The xxxx_Sniffer Flight.csv should be recreated and saved to the EMSA\Inputfiles-data directory
4. In case after 10 min the data is not imported contact should be made with Nabil Youdjou to fix the problem

Table 23 Example of Thetis-EU error message with the concerned record and a description of the error

missionId	Measuren	textlog

19052	BE2021042	{
		"ns0:createOrUpdateEmissionResponse": {
		"@xmlns:ns0": "http://eu/europa/emsa/thetis/integration/ws",
		"@xmlns:ns2": "urn:eu.europa.emsa.thetis.eu.deleteEmission",
		"@xmlns:ns1":
		"urn:eu.europa.emsa.thetis.eu.createOrUpdateEmission",
		"ns1:CreateOrUpdateEmissionResponse": {
		"ns1:Status": "VALIDATION_ERROR",
		"ns1:CreateOrUpdateEmissionErrors": {
		"ns1:ValidationError": {
		"@ns1:Code": "-2",
		"@ns1:MeasurementId": "BE20210427ODIN-RBINSOO-MMMR3",
		"ns1:Message": "Vessel IMO number is not valid"
		}
		}

5.4.2 Updating a record

To update a record with a new value it suffices to reopen the CSV file from the imported folder, change or update the record and save the record in the inputfiles-data directory. The database tool will automatically identify the updated value and will only change the corrected value. It is not required to delete the other records.

5.4.3 Thetis EU Data attributes

The data attributes and the description for the EMSA Thetis-EU database are provided in Table 24. It is very important to respect the formatting and formulas of the EMSA sheet of the xxxx-Sniffer Flight.xlsx file as this might influence the data export, therefore it is best to not change data in the EMSA sheet directly but only in the full data sheet.

Table 24 Attributes for data export to Thetis-EU

Element/Attribute	Comment	Example/Type	
MeasurementId		**BE**20170220112344567	Concatenation of: UNECE LOCODE of the MS (ISO2): 2-digit ISO code of the Member State; YYYYMMDD of the observation: The date of the observation; Local server Id: Identifier of the local server – "UNK" can be used for unknown; Device Id: Identifier of the device that took the measurements – "UNK" can be used for unknown; Source: "R" (stands for Remote); Message Sequence: Integer sequential identifier of each unique recorded measurement. It should be reset for each day of observation.
MemberState	ISO2 Code	"BE"	
MessageSequence	Sequential number	Sequential number: 1, 2, 3, 4, etc	
ServerID	Unique Identification of the transmitting server	Alphanumerical string	
DeviceID	Unique Identification of the used device (e.g. callsign plane, name of RPAS, code of shore based station) ; unique number	Alphanumerical string	
UpdateTime	Date and time (UTC) the msg was sent by the local server to EMSA	2014-03-14T14:15:27Z	
DateTimeOfOBS	Date and time of the observation/ measurement (UTC)	2014-03-14T14:15:27Z	
	A set of info related to the vessel identification, e.g. if the vessel is a ship, this could be the: - IMO, - MMSI, - Ship name, - Call Sign, - Fishing registry and Flag		
ObservationGeoPosition	Geographical - latitude and - longitude of position of ship during the vessel observation (may be an averaged figure for more than 1 measurement)	32.281986 -39.890083	
PositionInSeca	Yes/No		
PositionInEUPort	Yes/No		
VisualObservation	Free text field		
NumberOfMeasurements	Numerical value		
Contents	Derived Sulphur content in the fuel; Percentage, three digits behind comma	1%	
ContentUncertainty	The Sulphur measurement uncertainty	+-0.2%	
Concentrations	A set of gas concentrations as measured; could be SOx, CO2, NOx, etc.		

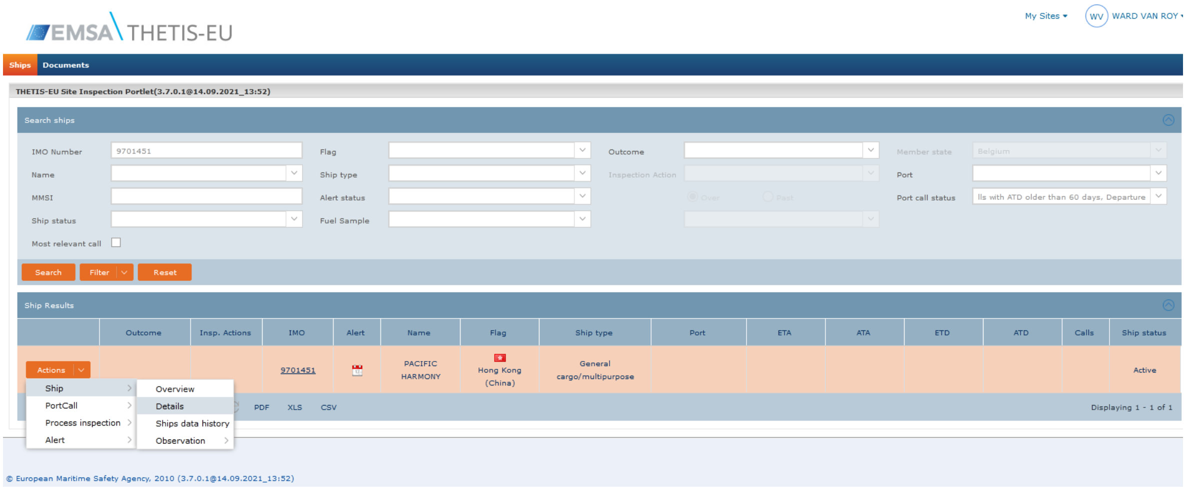
5.4.4 Checking if data upload was successful

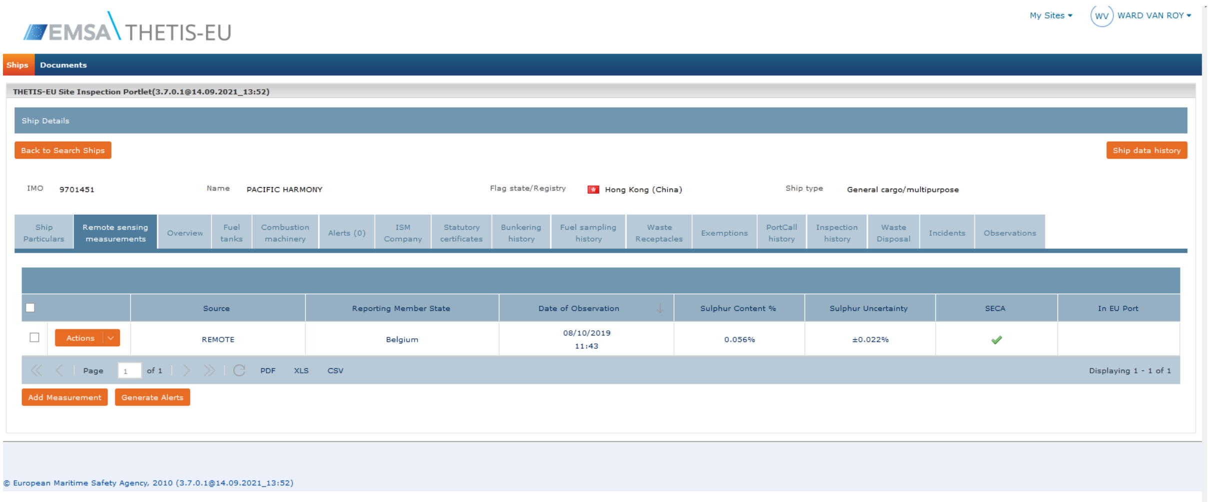
Once the data import process is completed the operator can manually check if the data was imported or not.

SOP 3.33. To check if the data export to Thetis-EU

1. Choose a certain ship
2. Copy the IMO number
3. Login to EMSA portal

   a. Go to https://portal.emsa.europa.eu/home
   b. Login with your EMSA account[6]
   c. Go to Thetis-EU>>Ships
4. Copy paste IMO number
5. Deselect "Most relevant call" checkbox
6. With "Port call Status": select "all"
7. Click search
8. If the ship exists in Thetis-EU the ship will be displayed
   a. Click on Actions (left column)
   b. Go to Ship>>Details
9. Go the "Remote measurements" tab
10. Check if the measurement is correctly available
11. For non-compliant data check if an alert is created





[6] For new users, an authorisation to grant access to Thetis-EU must be requested from the national Thetis-EU responsible (Bart Colaers from FOD Mobiliteit)

CHAPTER 6. REPORTING OF ANNUAL RESULTS

The creation of annual summarizing reports on the measurement results and the dissemination is important as this allows detailed statistical analysis but is also highly important for reporting to policy makers and stakeholders.

6.1. Annual sniffer data

A directory is made per year on the SQMQ directory

0. QMS\3. SNIFFER DM\Data analysis\Belgian Sniffer Campaign "Year"

This folder will contain 2 vital spreadsheets with the annual results

- "year" all data.xlsx
- Sniffer longerm results 2015-xxx

When creating a new annual report, a new folder should be made per year and the 2 spreadsheets should be copied and the title updated to the correct year

6.2. Yearly results

This file consist of all measurement data collected during the last year. This spreadsheet consist of the "full data" seet, the "ILT Sheet" and the "EMSA sheet".

6.2.1 Compiling the annual data

Only the full data sheet should be updated. The full data sheet has the same format and data structure as the full data sheets of the sniffer measurement files created per flight during the importing of the sniffer data (see Chapter 5). Due to periodic updates in the import procedure it is possible that the format or structure has changed during the year and has to be re-aligned.

SOP 3.34. To compile the data from individual sniffer measurement data

1. Open the directory with the measurement data per flight
2. \0. QMS\3. SNIFFER DM\IMPORT IGPS DATA\"Year"
3. Before data is added it is important that all "xxxx Sniffer Flight.xls" files have the same headers.
    a. Check the headers of first and last flight
    b. In case the headers are not the same check iteratively when headers changed (go each time to the middle of asubset of flights)
    c. Update the headers to the last version (add/move or delete columns)
4. If all data has the same columns, copy paste the "Full data per flight" in the yearly results
5. Add the flight number for every flight in the ILT sheet

6.2.2 Data cleaning

Once all data is added, the full data sheet with the annual results need to be cleaned up.

SOP 3.35. To clean the annual datashet

1. Remove all redundant "spaces" and @ characters
    a. Ctrl+h, with find what type 20 spaces

   - **b.** Click remove all
   - **c.** Remove a space every time and click remove all
   - **d.** Repeat until 1 space is left
   - **e.** Type "@" under find what
   - **f.** Click remove all
2. Harmonize the Flag states
   - **a.** Use the filter to look for repetitive flag states or flag states that can be combined
   - **b.** E.g. UK and GB
3. Check colour flags
   - **a.** Use the filter both on colour flags and FSC and
   - **b.** Check if all colour flags are correct with the FSC value
   - **c.** Check if colour flags and FSC values match with the HIGH/LOW
4. Check compliance
   - **a.** Use the filter both on Compliance and on Colour flags
   - **b.** Check if all High alerts correspond to a yellow, orange or red colour flag
   - **c.** Check if no FSC measurements are present with "Not Detected"

6.3. Updating Long term data

The long term data sheet consists of all measurement data from the start of the measurements in 2015. The file dates from 2016, at that moment only a limited amount of data was collected, as a result the data structure is much more limited than the data from the full data sheet, and consist of the dame data structure and format from the ILT sheet from the annual data spreadsheets.

6.3.1 Compiling

On annual basis the annual data needs the collected and added to the longterm datasheet

SOP 3.36. To compile the data for the longterm data spreadsheet

1. Open the "Sniffer Longterm results 2015-xxx. Xls" file
2. Go to the 2015-xxx sheet and update the year
3. Open the annual "xxx all data.xls" file
4. Check if the headers from the ILT sheet are the same than the main data sheet (2015-xxx)
   - **a.** Adjust the headers where necessary (add/move or delete columns in the ILT sheet)
5. Copy paste the data from the ILT sheet to the bottom of the 2015-xxx sheet
6. The last columns contain formulas and should be copied to the bottom

SOP 3.37. To add the fight data

1. Go to "Flights" sheet
2. Open the SURV Follow-up On Task "year".xls and open the Flights sheet
3. Select the flights related to Sniffer and ILT (use filter, skip blanks)
4. Copy paste the flight data to the bottom of the flights sheet

SOP 3.38. To add the data from Port State Control follow up and the fuel sampling

1. Update the a list of all reported alerts with the FSC value in the PSC follow up sheet
2. Request all data on fuel sampling from PSC
3. Copy paste the data in the fuel sampling sheet
4. Indicate which fuel samples have been performed after an alert
5. Update PSC follow up sheet

   - **a.** Add the FSC value(s)
   - **b.** add date in the
   - **c.** mark these ships as followed up by BE
6. Update PSC follow up sheet with data from Thetis-EU
   - **a.** Go to EMSA portal, Login and go Thetis-EU/Ships
   - **b.** Lookup which alerts (IMO nrs) were followed up for all reported alerts (see 5.4.4)
   - **c.** Copy paste the FSC content when available (and taken after the alert)
   - **d.** Add the date of the FSC analysis
   - **e.** Mark that the follow up was international and add the country in comments

6.3.2 Data cleaning

Several AIS attributes need to be harmonized to allow annual data compilations.

SOP 3.39. To clean the AIS data

1. Sort on the current year by using a filtering on the date/year
2. Harmonize the destination
   - **a.** Go to destination column
   - **b.** Use filter to see the different values
   - **c.** Sort per value
   - **d.** Values should be cleaned and harmonized with old values
   - **e.** Write the ports in English
   - **f.** Often a 5 digit code is used per port (BEANR is Antwerp)
   - **g.** Use a general terms for "waiting for orders" or "anchorage area"
   - **h.** In case only the country is available use "Na"
3. When updating the Destination from AIS add
   - **a.** Destination country (group the columns between Destination (AIS) and Destination country)
   - **b.** SECA/Out of SECA
4. Add type
   - **a.** Group the columns between the Type (code)
   - **b.** Use the AIS ship type categories
     - 30: Fishery
     - 37: Pleasure craft
     - 60-69: Passenger/RORO
     - 70-79: Cargo
     - 80-89: tanker
     - For military ship, check the name of the vessel (or code 35)
     - All others should get the "others" category
5. Deactivate all filters and do a last filter check on the full data set to remove any remaining doubles
6. For all violations check if the ship was equipped with a scrubber (available on Thetis-EU)

6.3.3 Recalculating FSC data

For harmonization of the data, all measurements can be recalculated using the raw measured data for SO_2, CO_2 and NO_x. Therefore the annual FSC span and offset can be calculated, in addition the NO/NO_x ratio and NO sensitivity need to be established.

SOP 3.40. Calculating annual FSC span and FSC offset

1. To get the lower reference value
    a. Collect 30 random FSC measurements from PSC (using XRF scanner)
    b. Calculate Median FSC value from PSC
2. To get the lower measurement value
    a. Recalculate the FSC for all measurements from the raw data
        - FSC = 0.233 x (SO2-NO/NOx ratio x NO CS_{NO} x NOx)/CO2
        - NO/NOx ratio = 0.8
        - NO CS_{NO} = 0.0045
        - The gas data is available in the full data file
            i. SO2 = columns: DI-DK
            ii. CO2 = columns: DL-DN
            iii. NOx = columns: DO-DQ
    b. Calculate the unbiased FSC data
    c. Calculate mean
3. To get the higher reference value
    a. Use the average of all the lab measurements of the plume simulation mixture
4. To get the higher measurement value
5. Use the average value for all the highest values of the measurements of the plume simulation mixture
6. With the two reference values and 2 measurement values the spann and offset can be calculated by entering these values in the SQMS_Follow-up.xls file in the CO2-SO2 sheet
7.

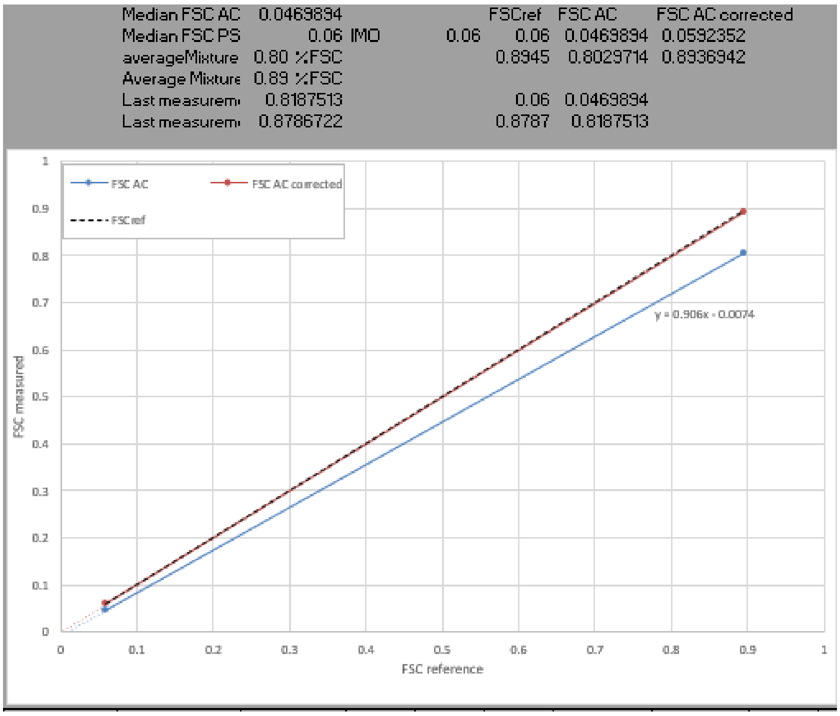


Figure 143 Calculation of annual FSC span and offset

SOP 3.41. Calculating NO/NOx ratio

1. The standard ratio is 0.8
2. To update the standard ratio measurements with both NO and NOx are used
3. Filter data with both NO/NOx measurements

4. Copy paste full data to new sheet
5. Use CO2 to calculate the NO/NOx
    - NO/NOx = $NO_i/CO2_i$ / $NOx_I/CO2_I$
    - Calculate average NO/NOx

SOP 3.42. Calculating cross sensitivity to NO

1. The last measured NO CS is 0.0045
2. To measure the NO CS the sniffer needs to be demounted and moved to the lab of the BIM
3. Install filter box at the air inlet of the sniffer
4. Install caps on the NOx tube connectors
5. Power on the sniffer using the GPU and the clip for ground operation
6. Connect the sniffer with laptop using an ethernet cable
7. Connect Thermo panel to the sniffer
8. Set Thermo on averaging time of 30 sec
9. Use gas mixing device to provide a mixture of NO in synthetic air with different intervals between 0 and 2000 ppb
10. Write down the SO2 measurement data per step once the measurements are stable
11. Make a graph and do a regression or trendline (with intercept = 0)
12. The slope is the NO CS factor
13. Update the NO CS in the AIS-Present ini file (see Annex B - Configuration file)
14.

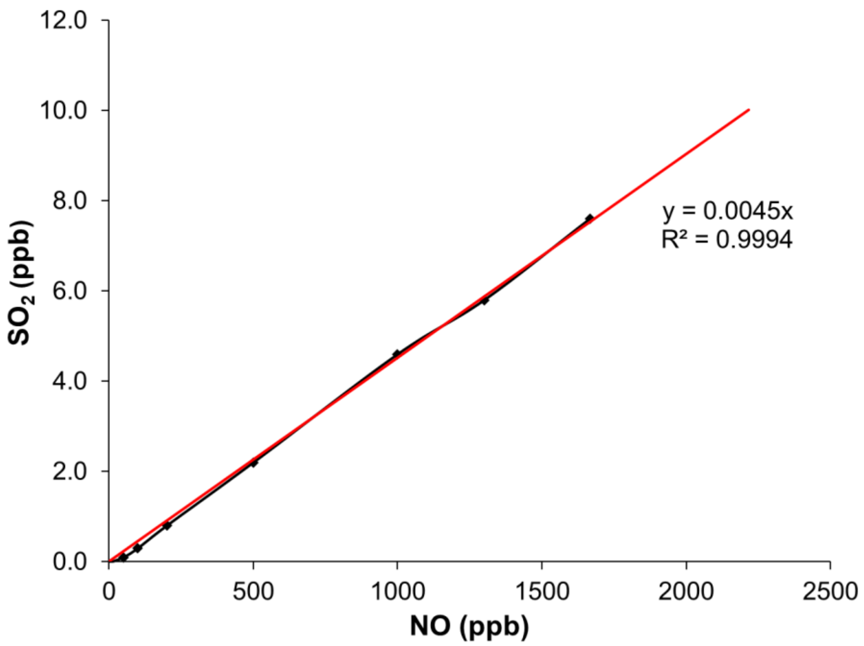


Figure 144 Calculation of NO CS

15.

SOP 3.43. Recalculating annual data

1. With the updated NO/NOx ratio
2. With the updated NO-CS
3. With the annual FSC span and offset
4. The FSC values can be recalculated
    a. FSC = Spann x 0.233 x (SO2-NO/NOx ratio x NO CS_{NO} x NOx)/CO2 + Offset
    b. The gas data is available in the full data file

- SO_2 = columns: DI-DK
- CO_2 = columns: DL-DN
- NOx = columns: DO-DQ

6.3.4 NOx data

In addition to the data compilation for the creating of the results on FSC. Some specific data processing is needed for the NOx data.

SOP 3.44. To clean, update and harmonize the NOx data

1. Check if all Tier levels are available and have a KLY if not add KLY
    a. Add KLY based on Thetis-EU
    b. Add KLY based on Built year from IMO/Marine traffic
2. Add maximum speed and check if for all possible violations have entered the engine parameters if not add data from following websites
    a. Thetis-EU
    b. https://www.fleetmon.com/
    c. https://ships.jobmarineman.com/
    d. https://shipnext.com/
    e. ..

6.4. Compilation of annual results

Once the data is cleaned, the summarizing table must be modified to include the new results

SOP 3.45. To update the overview sheet with the total results:

1. Go to the overview sheet
2. Add a column between the results per year and the total column
3. Copy paste the formula for each cell from the previous year updating the start and end of the rows for the new year
4. Modify the end row for the formulas in the total column

6.4.1 Updating graphs

Several graphs need updating, for those graphs either the data for the graphs needs to be update, a metadata table need to be updated, or the pivot table needs to be updated. As a full description for each graph would be too much time consuming this job needs to be done by an experienced data-analyst or under guidance of trained operator.

CHAPTER 7. DATA STORAGE AND BACKUP

This chapter described the tools that were developed to ensure a failproof data sharing system of vital sniffer data and the efficient archiving of backups.

7.1. Seafile

At this moment the sniffer data is not integrated in the SURV database. To make sure that the sniffer data is properly archived all data is regularly backed up on the Seafile cloud service either through an automatic synchronization process or by manual backups.

7.1.1 IGPS folders

IGPS folders on the laptop client stations are synchronized through seafile this makes sure that all operators have access to all measurements and use the same software versions and configuration during flight. Although some files are personal like the emission files and the collected AIS data. This means that for every user a separate file is made (naming is done based on the name of the machine on which the software is running).

7.1.2 SQMS

The SQMS folders include all aspects of operations of the sniffer and is shared through seafile. The structure is in line with the sections in the Sniffer Quality Management system:

- Sniffer OPS: The main content is the sniffer operational manual
- Sniffer QA: The main content is the SQMS Follow up and Sniffer Quality Assurance manual, this folder also includes the Technical reference docs and relevant manuals
- Sniffer DM: this includes all data analysis, LOG data, Imported data and the this Data Manual

7.1.3 Datastore folders

The datastore is a network location provided by RBINS, a folder of 4 TB was provided for surv and consists of the SURV mission archive. For long term safekeeping the raw data from IGPS folders should be annually backed up on the Datastore (see 7.3). The \surv location on the Datastore is shared through seafile through the laptop of Ward Van Roy and consist of following subfolders:

- 20-SURV-Flight-Reporting
- 21-SURV-Pictures
- 22-SURV-Movies
- 23-Mission Database Backup
- 24-International-Missions-Polex
- 25-Sensor data
- …
- 30-CSN Data

Note: although shared on Seafile these folders contain a high amount of data and should not be physically synchronized on the hard drives of the operator laptops.

To access the data-store a VPN connection is required. The Sophos SSL VPN client 2.1 application needs to be used to create a VPN connection. In some cases the software needs to be reinstalled due to issues with the initial installation.

SOP 3.46. To install the VPN software

1. Download and install Sophos SSL VPN Client 2.1 application from
2. 0. QMS\2. SNIFFER QA\Technical Reference Docs\VPN\OLD_VPN\
3. Download your configuration file
    a. Go to https://proxy.naturalsciences.be/userportal/webpages/myaccount/login.jsp
    b. and log in using your RBINS credentials (same Primetime)
    c. Download configuration for Other Oss from SSL VPN Client area.
4. After the installation go to "C:\Program Files (x86)\Sophos\Sophos SSL VPN Client\config" folder;
5. Delete the OVPN file
6. copy your xxx@rbins.be__ssl_vpn_config.ovpn file into
7. "C:\Program Files (x86)\Sophos\Sophos SSL VPN Client\config" folder

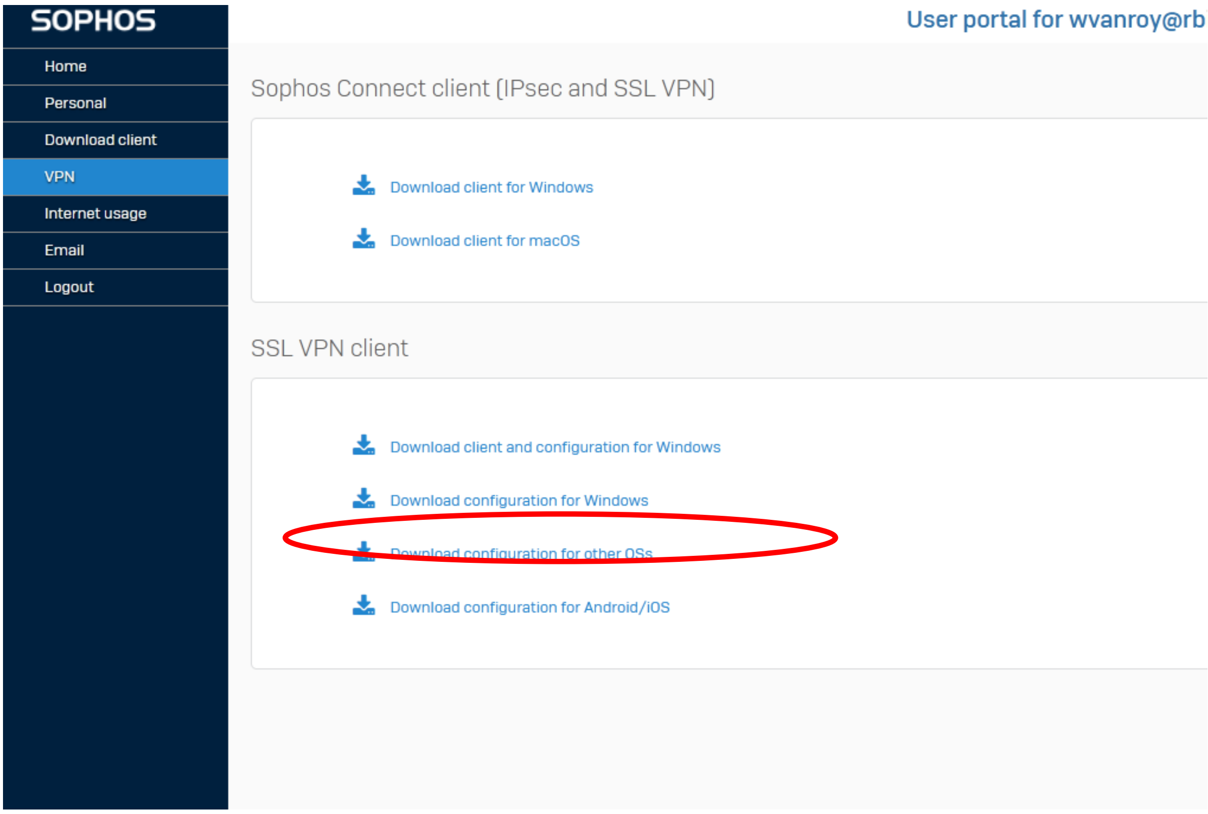


Figure 145 Sophos configuration file

SOP 3.47.

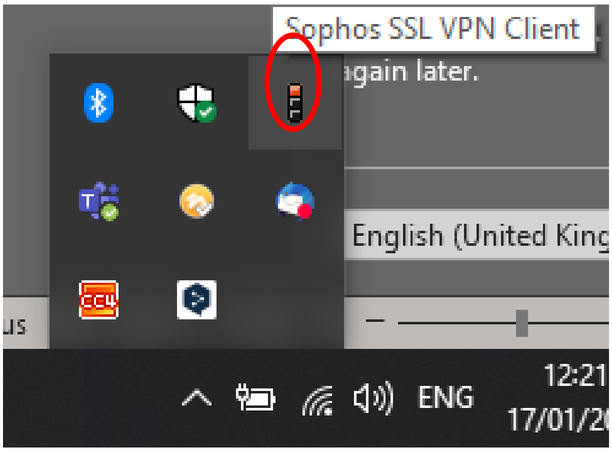
SOP 3.48. To re-install the VPN software after reinstallation

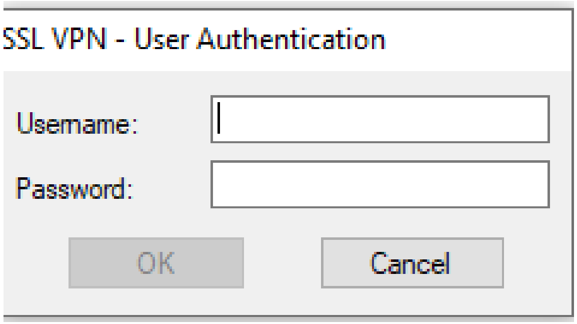
1. Go to "C:\Program Files (x86)\Sophos\Sophos SSL VPN Client\config" folder
2. Delete all OVPN files
3. Uninstall Sophos SSL VPN Client 2.1 application;
4. Repeat the steps 1-5 from SOP 3.47

SOP 3.49. To connect to the RBINS network

1. Launch the Sophos Open VPN software (location from start or search)

2. Right-click on the traffic light symbol in the right taskbar
3. Select “Connect”
4. A popup window appears for Authentication
5. Use your RBINS credentials and select “Ok”
6. The traffic light will become green once connected to the RBINS network





SOP 3.50. To access the datastore

1. Go to “This PC” in Windows Explorer
2. Right click and select “Map network drive”
3. Enter the “\\Datastorew\surv” path
4. The location will be opened, to create a shortcut, use ctrl+d or add to quick access or start

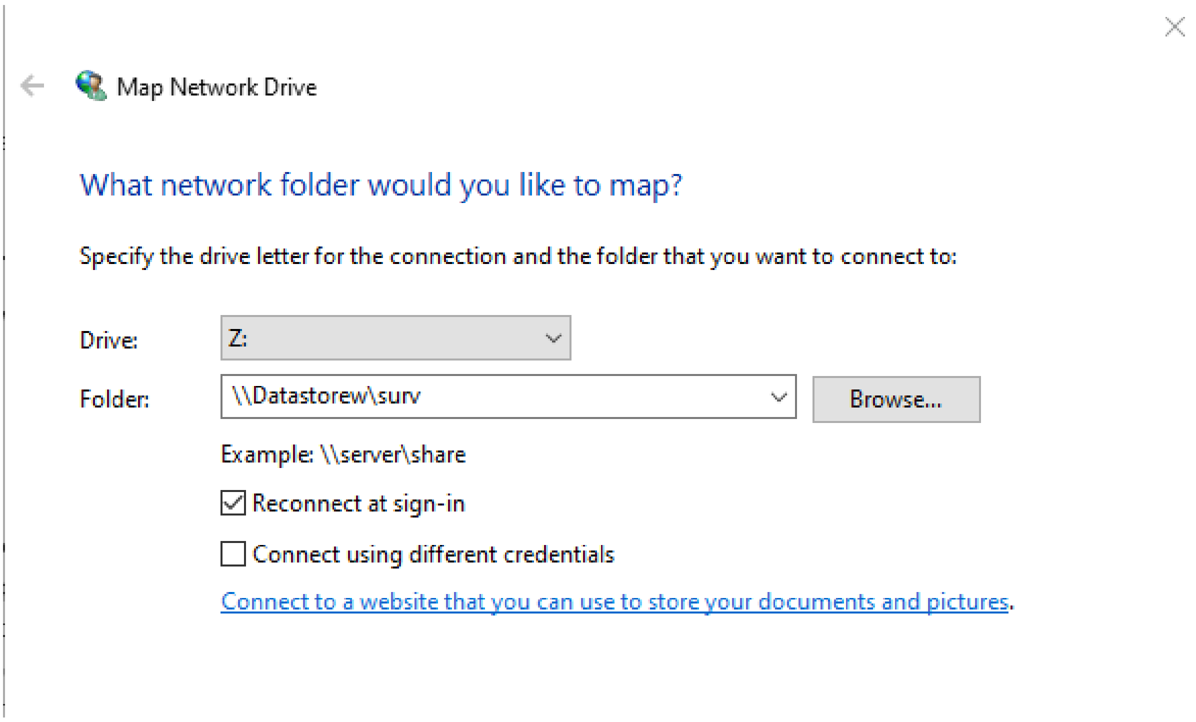


Figure 146 Map network drive to access Datastore

7.2. MUMM-LOG-PC

7.2.1 Software update

The IGPS software on the MUMM-LOG-PC does not undergo a regular updating cycle, but will only occasionally be upgraded e.g. when new features or sensors are requested from FluxSense/Chalmers. In addition it is important to perform an annual software backup.

SOP 3.51. To update the MUMM-LOG-PC

1. When:
   a. Update: as soon as a new stable version is available from FluxSense
   b. Backup: Every 12 months
2. General Equipment:
   a. Ground Power UNIT (GPU)
   b. Optional power cord to bypass AC power
3. Methodology
   a. Connect GPU to the AC
   b. Close the Watchdogs, TCP log, IGPS present, and all other files and programs
   c. Make a backup of the program files, log files and emission files from the IGPS folder from the LOG_PC (to 25-Sensor-Data/Sniffer/MUMM_LOG_PC Seafile)
   d. Copy the latest IGPS software to the IGPS folder on MUMM_LOG_PC
   e. Remove or rename the old “AISPresent.exe” version
   f. Rename the new version to “AISPresent.exe”
   g. Shut down the MUMM_LOG_PC
   h. Power off the sniffer, wait 10 seconds and power on the sniffer
   i. Reboot the sniffer

7.2.2 Annual SSD cloning

It is important to perform an annual back up of the SSD installed in the MUMM-LOG-PC, this will allow a last resort solution for serious software malfunctioning.

SOP 3.52. To Clone SSD

1. **When**: Every 12 months
2. General Equipment:
   a. Ground Power UNIT (GPU)
   b. Optional power cord to bypass AC power
3. Methodology:
   a. Connect GPU to the AC
   b. Close the Watchdogs, TCP log, IGPS present, and all other files and programs
   c. Make a backup of the program files, log files and emission files from the IGPS folder from the LOG_PC (to 25-Sensor-Data/Sniffer/MUMM_LOG_PC Seafile)
   d. Place SSD-2 in Kingston drive case and connect to USB port on the back of the sniffer
   e. Power on the Sniffer sensor
   f. Connect to the MUMM_LOG_PC using TeamViewer
   g. Close all programs and files
   h. Open Samsung Data-Migration software

i. Run the cloning software, make sure both drives area visible, select start (cloning will take 30 min)
j. Shut down the Sniffer sensor
k. Disconnect the SSD

In case of SSD failure or significant software issue, the SSD1 can be replaced with SSD2. To replace the SSD see Section 2.

Note: Do not override the original HDD, this should be kept for safekeeping,

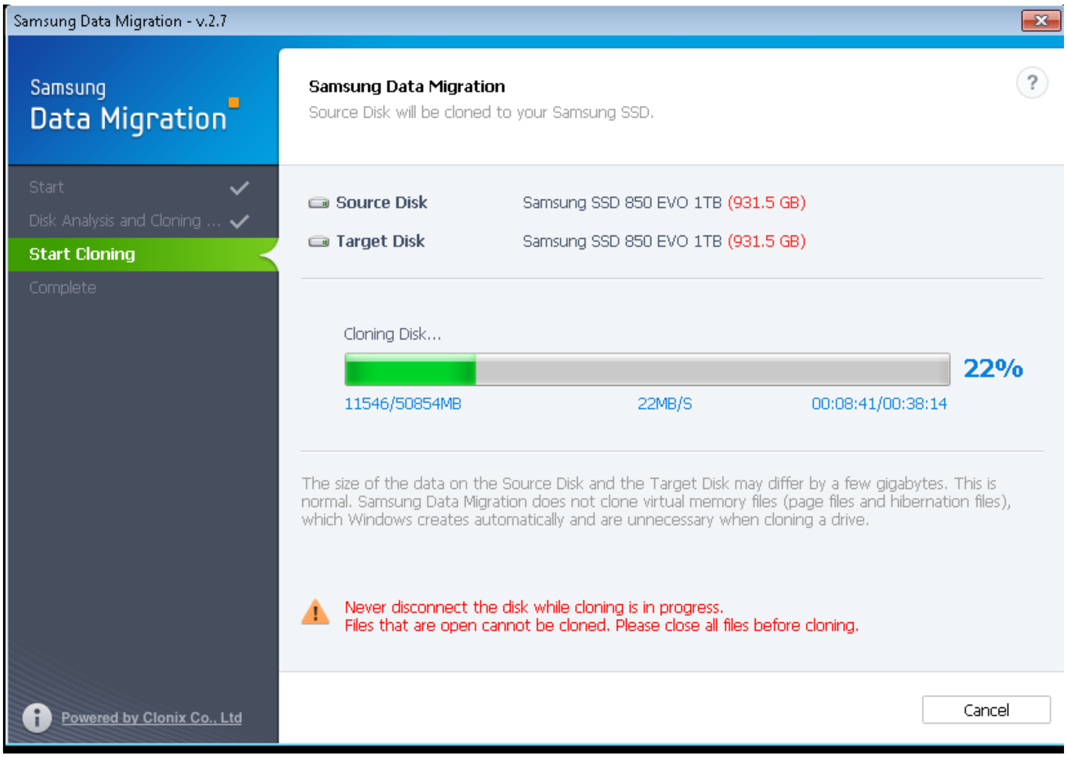


Figure 147 Samsung data migration software

7.3. IGPS directory maintenance

The IGPS folder contain all software data and data reference files for the proper functioning of the IGSP software. On annual or bi-annual basis a cleaning and update of the data reference files should be executed to continue to proper functioning of the software and data import tools. The IGPS folders for the operator laptops are synched through seafile, so for these folders maintenance needs to be performed only on one PC. For the MUMM-LOG-PC the same maintenance needs to be repeated with in addition a backup of the log files, the MEDUSA PC is not used for measurements but for uniformity it is advised to update the data reference files and clean the IGPS directory together with the MUMM-LOG-PC.

7.3.1 MIDs

The MID data is used by the IGPS software to identify the flag state of the ships based on their MMSI number. The MMSI MID country codes should be updated on annual basis or when crashes or commonly observed. The official list of MIDs can be found in a document called “Table of Maritime

Identification Digits" and can be found at ITU (https://www.itu.int/en/ITU-R/terrestrial/fmd/Pages/mid.aspx).

SOP 3.53. To update the MID data

1. Open the file AISPresent.ini, located in the same directory as AISPresent63.exe
2. Search for the tagg MIDS (see **Annex B - Configuration file**)
3. Scroll down to the appropriate location of the list, eg. 259 if a country code for MID 260 should be inserted.
4. Add a new row with the following content [new MID] =[new MID], [two char territory abbreviation],[three char country abbreviation],,[name of territory]

E.g, for a ship from Ursa Minor with a MID of 260 the line would be: 260=260,UM,URM,,Ursa Minor

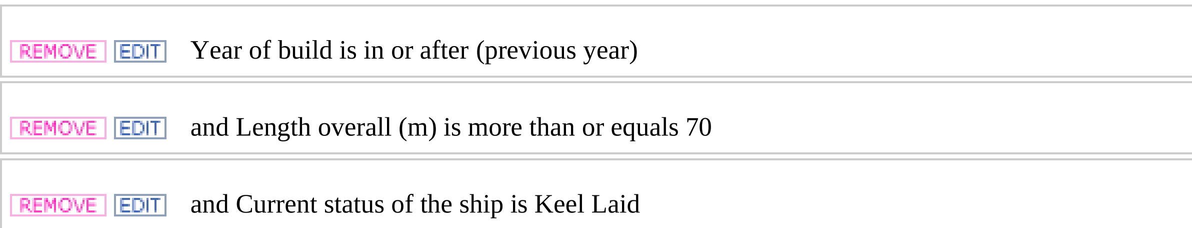
Note that the ini files on all client station need to be updated, to avoid errors with other configuration settings it is recommended to do this procedure for the Laptops, Console and MUMM-LOG-PC separately.

7.3.2 Update MMSI-Keel Laying Date

Keel Laying Date (KLD) is used to identify the Tier level of ships. KLD information is made offline available to the operators during flight.

SOP 3.54. To update KLY dataset (MMSI_Date.csv)

1. Open the last keel laying data import file
   a. Go to 0. QMS\3. SNIFFER DM\Data reference files\Keel laying date\"YEAR"
   b. Copy IMO_Keel-laying-date.xls to a new "Year" folder
2. Go to GISIS Website: https://gisis.imo.org/Public/Default.aspx
3. Go to Login
   a. Type: Member state/ Authorization
   b. Country: Belgium
   c. Login using your credentials
4. Go to Ship particulars
5. Go to Advance search
   a. Select start year
   b. Select Length overall (>70)
   c. Select status Keel laid



6. Select download
   a. Do the same but select in service/commission
   b. Select start year
   c. Select Length overall (>70)
   d. Select status In Service/Commission
7. Select download

8. Combine both results
9. Do cross reference with old data (remove doubles that are already present)
    a. Keel-laying-dates IMO-MMSI-Vx-x-x-202x.xls
10. Add non doubles with information (IMO number, name, flag, GT, type, status, year of build, registered owner) to the end of the list in the SHIPS sheet (Keel-laying-dates IMO-MMSI-Vx-x-x-202x.xls)
11. Create **list nr 1** with all IMO numbers (including the old data)
    a. This list will be updated by EMSA to provide updated MMSI numbers: Celia.CACIONES@emsa.europa.eu
    b. Once the list is updated the updated MMSI data should be copied replacing the old numbers, in case the data is missing, the old MMSI numbers should be kept
12. Create **list nr 2** with IMO nr and Year built of new ships
    a. This list will be updated by EMSA to provide keel laying years: Celia.CACIONES@emsa.europa.eu
    b. all ships that had status keel laid at GISIS in 2020, but without the provision of an exact keel laying date from EMSA should have a keel laying year of 2020
    c. Copy the new ships to the xls file, keep the additional data on GT, …
13. Create a new CSV file
    a. Go to the sheet “CSV manual”
    b. Copy past the MMSI to the first column (as values)
    c. Copy paste the Keel Laying Dates to the second column (as values)
    d. Save excel file first
    e. With the “CSV manual” sheet open, save as “MMSI_Date.csv”
    f. Copy and replace the new csv file to IGPS folder
    g. keep backup of the old file with date in title in the

7.3.3 Cleaning IGPS data

The IGPS folders will collect the measurement data, to free up space and to speed-up the importing procedures the IGPS folders on each client station should be backed up and cleaned. The full content of the IGPS folders (except the charts) should be copied every year and stored on the Datastore network location Surv-Disk\25-Sensor-Data\04-SNIFFER DATA\Backup Emission and LOG data\”Year”. Following folders should be created per year

- IGPS folder shared on Seafile (client stations)
- IGPS folder from MEDUSA
- IGPS folder from MUMM-LOG-PC

After copying the following files should be deleted from the different IGPS folders:

- All content from the “Missions-Data” Directory
- All content from the “MAIL” Directory
- All “Emissiondata_xxx.txt” files
- “Mail_Sniffer_SO2_Man_Meas.csv” file
- “Comments _xxx.txt” and “Comments” directory content

For the IGPS folder on the MUMM-LOG-PC the content from the TCP log folder should also be deleted.

CHAPTER 8. REFERENCES

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https://www.bronkhorst.com/products/pressure/el-press/p-502c/

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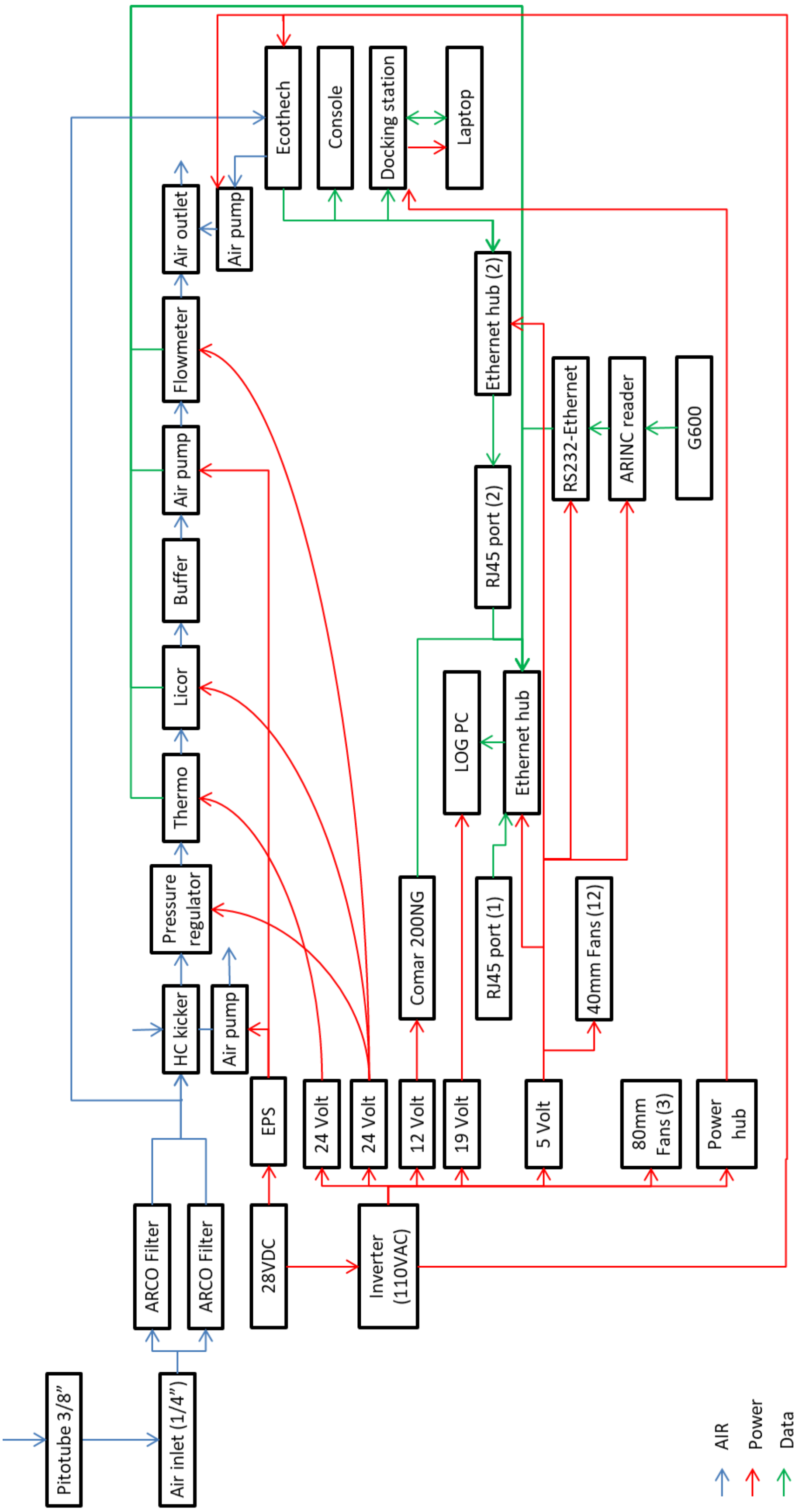
ANNEX A - BLOCK DIAGRAM



ANNEX B - CONFIGURATION FILE

```
#[
#MAC_SNIFFER=00012E4D9E04
[GASES]
#DEPRICATED=DATA now in section [SITE-GASES]
[SETTINGS]
InfoBalloon=0
InfoBalloonFontSize=8
CompassFontSize=8
MY-MMSI(EXCLUDED)=-1
CompassFontBlackOnWhite=1
CompassSimple=1
APPERENT_WIND=0
UPDATE_SO2CO2_DIAGRAM=1
SHOW_MY_TRACK=1
SHOW_SHIP_TRACK=1
LIVE_WIND=1
SHOW_LANDMASS=1
GPS_HEADING=1
WIND_FILTER=1
SHOW_COMPASS=1
IS_AUTO_CALIBRATOR=0
LOG_TO_FILE=0
ALLWAYS_CONNECT_TO_REMOTE_ON_START=0
TRANSP_LABELS=1
SHOW_COMMENTS_IN_DIAGRAM=1
SAVE_LOCAL_TCPDATA=0
SHOW_NOXCOMMANDS=0
CO2_OFFSET=381
SO2_GAIN=30
SHOW_BEARING=1
HIGH_SENSITIVITY=0
PlotFontSize=9
CURSORLATLONGFORMAT=1
ShowAllWindArrows=0
PlotShipsRegardlessOfPosQuality=1
ShowShipInfoBalloon=1
SHOW_START_AND_UP_TIME=1
ALWAYS_CONNECT_TO_REMOTE_ON_START=0
WindArrowAlongWind=1
[SITE-GENERAL]
SLOW-SO2=0
NORMAL-SO2-ORDER=0
[SITE-WIND]
AIRMAR_WIND_SELECTION=3
AIRMAR_WIND_DO_ADJUST=0
AIRMAR_WIND_OFFSET=0
DirLeft(lower)LimitDeg=-1001
DirRight(upper)LimitDeg=-1001
DirLeft(lower)LimitWideDeg=-1001
DirRight(upper)LimitWideDeg=-1001
[SETTINGS_META]
TILE_DIR=C:\IGPS\Charts
XMLCONFIG=default
BASE-OUTPUT-DIR=C:\IGPS\
[NOX_params]
MMSI_DATE_DIR = C:\IGPS\MMSI_Date.csv
KWH_Factor = 0.2
NO_Delay = 4
```

```
NOx_Delay = 5
NO_Interference = 0.45
NONOx_Ratio = 0.8
FSC_Span = 1.2571
FSC_Offset = 0.0007


[E-MAIL-SFC-ALERT]
MailAbove=100
[E-MAIL-QUEUE]
CONTAINING-FOLDER=C:\IGPS\
[MIDS]
-111=-111,IM, IOM,,Isle of Man
201=201,AL,ALB,,Albania
202=202,AD,AND,,Andorra
203=203,AT,AUT,,Austria
204=204,PT,PRT,PT-20,Azores
205=205,BE,BEL,,Belgium
206=206,BY,BLR,,Belarus
207=207,BG,BGR,,Bulgaria
208=208,VA,VAT,,Vatican City State
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210=210,CY,CYP,,Cyprus
211=211,DE,DEU,,Germany
212=212,CY,CYP,,Cyprus
213=213,GE,GEO,,Georgia
214=214,MD,MDA,,Moldova
215=215,MT,MLT,,Malta
216=216,AM,ARM,,Armenia
218=218,DE,DEU,,Germany
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224=224,ES,ESP,,Spain
225=225,ES,ESP,,Spain
226=226,FR,FRA,,France
227=227,FR,FRA,,France
228=228,MT,MLT,,Malta
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230=230,FI,FIN,,Finland
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254=254,MC,MCO,,Monaco
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308=308,BS,BHS,,Bahamas
309=309,BS,BHS,,Bahamas
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323=323,CU,CUB,,Cuba
325=325,DM,DMA,,Dominica
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447=447,KW,KWT,,Kuwait
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453=453,MO,MAC,,Macao
455=455,MV,MDV,,Maldives
457=457,MN,MNG,,Mongolia
459=459,NP,NPL,,Nepal
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463=463,PK,PAK,,Pakistan
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471=471,AE,ARE,,United Arab Emirates
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477=477,HK,HKG,,Hong Kong
478=478,BA,BIH,,Bosnia and Herzegovina
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514=514,KH,KHM,,Cambodia
515=515,KH,KHM,,Cambodia
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520=520,FJ,FJI,,Fiji
523=523,CC,CCK,,Cocos (Keeling) Islands
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531=531,LA,LAO,,Lao People's Democratic Republic
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760=760,PE,PER,,Peru
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770=770,UY,URY,,Uruguay
775=775,VE,VEN,,Venezuela
[SITE-CAL_COEF]
CO2b_ValueOfRefGas=1
CO2b_MeasuredRef=1
CO2b_MeasuredZero=0
SO2_ValueOfRefGas=264
SO2_MeasuredRef=291.8
SO2_MeasuredZero=0
NOx_ValueOfRefGas=1
NOx_MeasuredRef=1
```

```
NOx_MeasuredZero=0
[CAL_COEF]
#DEPRICATED=DATA now in section [SITE-CAL_COEF]
[SITE]
PlatformID=MUMM
PositionLatDeg=48.9300150
PositionLonDeg=-5.5955283
FilterEnabled=0
FilterLengthPost=0.0
FilterLengthPre=5.0
CO2_FilterEnabled=0
SO2_FilterEnabled=0
NOx_FilterEnabled=0
CO2_MeanFilterLength=0.5
SO2_MeanFilterLength=0.5
NOx_MeanFilterLength=0.0
[POLY]
1=SECA_W_HATCHED,CLOSED;0x008F8CC5,0,0x008F8CC5,bsFDiagonal;48.5,-5.0; 50.0,-5.0; 50.0,-4.9; 48.5,-4.9
2=SECA_W_LINE,OPEN;0x008F8CC5,2,0x008F8CC5,bsClear;48.5,-5.0;50.0,-5.0
3=SECA_NW_HATCHED,CLOSED;0x008F8CC5,0,0x008F8CC5,bsFDiagonal;58.5,-4;62.0,-4;62.0,5;61.95,5;61.95,-3.9;58.5,-3.9
4=SECA_NW_LINE,OPEN;0x008F8CC5,2,0x008F8CC5,bsFDiagonal;58.5,-4;62.0,-4;62.0,5
101=BE_EEZ_HATCHED,CLOSED;0x008F8CC5,0,0x008F8CC5,bsBDiagonal;51.067181,2.466578;51.26917,2.290278;51.5577
8,2.138333;51.61306,2.153333;51.805,2.381667;51.94,2.536;51.55167,3.181389;51.433362,3.407997;51.378627,3.45258
8;51.372891,3.463;51.391547,3.441897;
51.368981,3.366396;51.372891,3.363;51.378627,3.352588;51.433362,3.307997;51.55167,3.081389;51.87611,2.539333;5
1.805,2.481667;51.61306,2.253333;51.55778,2.238333;51.26917,2.390278;51.089876,2.544952
102=BE_EEZ_LINE,OPEN;0x008F8CC5,2,0x008F8CC5,bsClear;51.089876,2.544952;51.26917,2.390278;51.55778,2.238333;5
1.61306,2.253333;51.805,2.481667;51.87611,2.539333;51.55167,3.081389;51.433362,3.307997;51.378627,3.352588;51.3
72891,3.363;51.368981,3.366396
;100=# Usage:
;101=#
nnn=name,PolyType;PenColor,PenWidth,FillColor,FillStyle;LatDeg1,LongDeg1;LatDeg2,LongDeg2;..;LatDegN,LongDegN
;102=#    nnn              unique integer number
;103=#    name              A symbolic name for this path/region ( Only _ | A..Z | a..z | 0..9 )
;104=#    PolyType           CLOSED|OPEN
;105=#                    CLOSED  A closed region given by the lat/long-pairs
;106=#                    OPEN:   A line through the give lat/long-pairs
;107=#    PenColor/FillColor    An integer ex. 0x00bbggrr
;108=#                      b,g,r: 0..9|A..F
;109=#                      b:blue,g:green,r:red
;110=#    FillStyle          bsSolid|bsClear|bsHorizontal|bsVertical|bsFDiagonal|bsBDiagonal|bsCross|bsDiagCross
;111=#                     applies only to CLOSED polys
;112=#                     dont care for OPEN polys
;113=#    LatDeg/LongDeg      Floating point number in DEG (decimal point)
[VISIBLE-TABS]
TabARINC_FRQ=1
TabSheetGas=1
TabSheetGlobalMap=1
TabSheetComments=1
TabSheetAnalogValues=0
TabSheetEEPSStatus=0
TabSheetNOx2Diagram=0
TabSheetNOx1Status=0
TabSheetIK=0
TabSheetDev=1
TabSheetAirmar=0
TabSheetPicarro=0
TabMailSetup=0
Tab2=0
TabSheetPlotsConf=1
TabSheetOPT=0
TabSheetGlobalWEB=0
[PLOTCO2.VISIBLE-TRACES]
```

```
1=0
0=1
2=0
6=1
7=0
8=1
3=0
4=0
5=0
9=0
10=0
11=1
12=0
13=0
14=0
[UNITS]
WindSpeed=kt
ShipSpeed=kt
SensorSpeed=kt
[PLOTNOX.VISIBLE-TRACES]
19=1
0=0
1=0
2=0
3=0
4=0
5=0
6=0
7=0
8=0
9=1
10=1
11=0
12=0
13=0
14=0
15=0
16=1
17=0
18=0
20=0
[PLOTSO2.VISIBLE-TRACES]
0=1
1=0
2=0
3=0
4=0
5=0
6=0
7=0
8=0
9=0
10=0
11=0
12=0
13=1
[SITE-GASES]
GAS0=0,0,0,0,0,0,0,0,0,0,1,60
GAS1=0,0,0,0,0,0,0,0,0,0,2,60
GAS2=0,0,0,0,0,0,0,0,0,0,3,60
GAS3=0,0,0,0,0,0,0,0,0,0,4,60
GAS4=0,0,0,0,0,0,0,0,0,0,5,60
CurrentGas1=0
```

```
CurrentGas2=1
CurrentGas3=2
CurrentGas4=3
CurrentGas5=4
```

ANNEX C - FLIGHT REPORT

BMM
BEHEERSEENHEID VAN HET MATHEMATISCH MODEL NOORDZEE
Koninklijk Belgisch Instituut voor Natuurwetenschappen

UGMM
UNITÉ DE GESTION DU MODÈLE MATHÉMATIQUE MER DU NORD
Institut Royal des Sciences Naturelles de Belgique

Ostend B-8400 / 3de en 23ste Linieregimentsplein
Brussels B-1200 / Gulledelle 100
TEL: +32 2 773 21 11 / FAX: +32 2 773 21 12 / EMAIL Aerial Surveillance: surv@naturalsciences.be

BELGIAN FLIGHT REPORT OF OBSERVATION AT SEA

Flight Nr. 18142

ORIGINATOR OF THE REPORT

Aircraft registration:	OO-MMM	Flight operator's name	VAN CAPPELLEN Maarten	Mobile:	+32 496 18 38 22
TO: MIK - Maritiem Informatie Kruispunt		EMAIL: mik@mil.be / FAX: +32 50 55 83 19		Page (s)	1+0

MESSAGE CODE

DTG	ddmmyy: 100918	hhmm: 1104	UTC						
P	I								
C	R	Area							
Sx	S 1 LTD	Pollution	BE						

Fax & Email RECIPIENT LIST (For Mik use)

1. FOD Leefmilieu 02-524.96.43 / marien.milieu.marin@environment.belgium.be
3. BMM Brussel 02-773.21.12 / surv@naturalsciences.be
4. PSC Env. Adm. sulphur@mobilit.fgov.be

0
0
0
0

OBSERVATION

FURTHER ACTION REQUIRED	NO
OBSERVATION OF	Marpol Annex VI Emission

DATE / TIME: ddmmyy: 100918 | hhmm: 1019 | UTC

POSITION: EEZ — See Annex

Nr	Area	Time UTC	Lat.	Long.	Length (km)	Width (km)	Remarks
1.	BE	1019	51° 46' 23" N	2° 34' 13" E	0	0	MAERSK MIYAJIMA
2.							
3.							
4.							
5.							
6.							

DESCRIPTION

POLLUTION

Type of substance	Sulphur
Estimated quantity	0.42%
Combatable	NO
Polluter identified	MAERSK MIYAJIMA
Marpol scenario	

NATURAL PHENOMENA

Description:

OTHER OBSERVATION

Description:

Platform/Ship involved:

PICTURES

PICTURES AVAILABLE

ANNEXES

- BA Pollution Observation Log (Annex A)
- BA Pollution Obs. Report on Polluters and Combatable Spills (Annex C)
- BA Standard Algae Report (Annex D)
- Annex on windmill-park activities
- Annex with photos

FURTHER REMARKS & TYPE OF FURTHER ACTION REQUIRED

MMSI : 357616000
Callsign : 3FUP9
Name : MAERSK MIYAJIMA
Shiptype : 80 (Tanker)
Destination : KILLINGHOLME, UK
Dimension : 177m x 32m
IMO number : 9500905
ETA : 09/11 08:00 (MM/DD hh:mm)
Last position : N 51° 46' 24" / E 002° 34' 13"
FSC: 0.42% confirmed by second measurement 0.74% RED FLAG