

GE
Grid Solutions

Transport X² Operator Guide

Portable Dissolved Gas Analysis



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Abbreviations & Definitions

Abbreviation	Meaning
AC:	Alternating Current
CH ₄ :	Methane
C ₂ H ₂ :	Acetylene
C ₂ H ₄ :	Ethylene
C ₂ H ₆	Ethane
CO	Carbon monoxide
CO ₂	Carbon dioxide
DC	Direct Current
DGA	Dissolved Gas Analysis
ESHL	Estimated Safe Handling Limit (ESHL)
ETRA	Electric Technology Research Association
GE	General Electric
HMI	Human Machine Interface
H ₂	Hydrogen
H ₂ O	Water
Hz	Hertz, a unit of frequency equal to a cycle per second
ID	Identification
IEC	International Electrotechnical Commission
LDL	Lower Detection Limit
LEL	Lower Explosive Limit
LTC	Load Tap Changer
N ₂	Nitrogen
ppm	Part Per Million, representing the concentration of a gas in transformer oil
RS / RH	% Relative Saturation / Humidity
TDCG	Total Dissolved Combustible Gas
Transport X ²	Portable Dissolved Gas Analyzer (the product)
UDL	Upper Detection Limit
VAC	Volt Alternating Current
W	Watt
WEEE	Waste Electrical and Electronic Equipment (European Union directive)

1 INTRODUCTION

1.1 Product Overview

Transport X² (the product) is a portable Dissolved Gas Analysis (DGA) and moisture monitoring system for analysing insulating fluids in the field across electrical generation, transmission, distribution and industrial applications. The product utilizes advanced photo-acoustic spectroscopy (PAS) technology to obtain measurements of critical fault gases and now supports the testing of multiple oil types including ester-based fluid (natural or synthetic). The product measures seven certified fault gases: *hydrogen, methane, ethane, ethylene, carbon monoxide, carbon dioxide, acetylene* and moisture levels in the transformer oil. The ability to deliver accurate, reliable and on-the-spot results in the field allow the early detection of potential faults thereby avoiding costly outages and ensuring asset optimization. Such data provides insight on transformer condition, such as developing faults and paper degradation.

The product builds on the success of its predecessor with a redesign that affords a lighter and more compact form. The product's top panel has been reconfigured with a failure-proof injection method, a new improved graphical user interface for a more intuitive user experience with plug and play support for downloading measurements and log files using a standard USB 2.0 memory stick.

The product offers several onboard software-based analytical and diagnostic tools for examining DGA results. These are based on widely recognized industry standards in conjunction with various user-configured caution and warning alarm limits. All results are stored within the product, but can also be downloaded to a PC for further analysis, aggregation and trending with the Perception software suite. The product offers seamless connectivity to Perception via USB without the need for third-party software (see Appendix B: Download Transport X2 data to Perception).

The product represents a new generation of portable test equipment and is contained within a new style, impact-resistant, rugged carrying case. The accessories to perform the DGA tests are contained within a separate lightweight case.

1.2 Scope

This guide gives important technical details including how to correctly configure the product for use and how to set up the equipment to measure a sample. It outlines key usage points and explains the functionality of the product through the onboard HMI touchscreen – specifically creating new measurements, viewing results and using the onboard analysis tools. This guide also explains how to prevent contamination, perform a variety of integrity tests and troubleshoot any issues.

To ensure optimum performance of the product, it is important to read this manual fully before use. Some difference to the procedures contained within this guide depend on whether the sample is oil or gas. Most functionality is illustrated using an oil sample, but any differences to the procedures for gas samples are also outlined.

2 SAFETY

2.1 Symbols

The meaning of symbols used in this guide:



A procedure, practice, or condition could cause minor injury, equipment damage or loss of data.



Electrical Hazard: Risk of electric shock.



Do not dispose of with household waste. Dispose of at an appropriate recycling facility. GE recommends that you follow local WEEE requirements or alternatively contact ge4service@ge.com for further information on returning your product.

2.2 Warnings & Cautions

The following warnings and cautions must be observed:



Do not operate the product (i.e. with the top cover open) when raining or during other adverse environmental conditions to prevent exposure to the elements or other contaminants.



If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.



Do not use the product if the power cord is damaged or if the protective earth pin is damaged.



Use only a safety-approved power cord.



Disconnection from the supply is achieved through the power inlet connector. To disconnect from the supply, turn off the product using the touchscreen, power off using the On / Off rocker switch and then disconnect the supply cord.



Use only the approved and recommended fuse to ensure continued fire protection and compliance.



There are no serviceable parts within the product.



The product should be stored with the lid closed when not in use to avoid accidental damage during transit.



The product should not be left operating unsupervised.

2.3 Hazardous Substances

The gases measured in the product are extracted from the oil and expelled to the atmosphere. All expelled gases are at concentrations that are quickly diluted in the surrounding atmosphere and are not hazardous to health or life.

To provide reassurance, the Estimated Safe Handling Limit (ESHL) is implemented to assess the associated risk with handling the oil sample. The ESHL expresses the total concentration of gases within the oil sample as a percentage. This percentage ESHL value is shown as 'Flammability in air' on the results screen and on the results printout. The ESHL is calculated using the ppm values of the Lower Explosive Limit (LEL) of each gas in the oil. Table 2-1 lists the ppm values of the LEL for each gas (if the oil is saturated with air).

Table 2-1: Lower Explosive Limits

Gas	LEL (ppm)
Hydrogen	2,232
Methane	23,214
Carbon Monoxide	16,625
Ethane	77,700
Ethylene	54,560
Acetylene	30,500

For most samples, this is typically 0% (or a low percentage value), but oil sampled from a Load Tap Changer (LTC) compartment may have higher percentage value so care must be taken when handling this oil.

Note: As a precaution, samples should be handled only when it is considered safe, and when no potential fire sources are near the sampling area.

2.4 Waste Oil Disposal



Waste oil should be disposed of in accordance with local regulations and company policies.

2.5 Handling & Storage

The product is shipped in a cardboard carton with foam pieces, sealed and wrapped in a plastic liner or in an optional transit case.



Handle units with care and avoid significant shocks such as dropping from a height. The units can be stacked to a maximum of three high.

For storage, customers are requested to store the product in a fully enclosed building that is free from damp and extremes in ambient temperature. The storage facility temperature must be between 5 °C and 50 °C.



The product should not be stored in a vehicle if it is possible for the temperature to be outside of the stated temperature range.

Note: Customers are fully responsible for ensuring that stacked pallets are stable and, if necessary, providing additional external support. Damage incurred by improper customer handling or storage will not be covered under warranty.

3 TECHNICAL SPECIFICATIONS

The product meets the following technical specifications as outlined in Table 3-1.

Table 3-1: Technical Specifications

PARAMETER	VALUE/MEETS	
MEASUREMENTS ^{*1 & 6}	LDL (ppm)	UDL (ppm)
Hydrogen (H ₂)	5	5,000
Methane (CH ₄)	2	50,000
Ethane (C ₂ H ₆)	2	50,000
Ethylene (C ₂ H ₄)	2	50,000
Acetylene (C ₂ H ₂)	0.5	50,000
Carbon Monoxide (CO)	2	50,000
Carbon Dioxide (CO ₂)	40	50,000
Gas measurement accuracy ^{*2 & 3}	± LDL or ± 5%	
Moisture (H ₂ O) – Relative Humidity ^{*4}	0 to 100% RH	
Moisture measurement accuracy	± 3 ppm or ±3% RH	
Buchholz gas measurement & accuracy	LDL is 50 ppm, accuracy is ± 30% for all gases	
ENVIRONMENTAL		
Operating temperature range	5 °C to 50 °C (41 to 122 °F)	
Operating altitude	Up to 2000 m	
Operating pressure	760 to 1040 mbar	
Operating humidity	10 – 95% RH non-condensing	
Enclosure	IP67 (when closed) IP20 (when operating)	
Oil sample volume (mineral or ester)	50 ml	
Gas sample volume (Buchholz)	5 ml	
Dimensions (L x W x H)	429 x 328 x 236 mm (16.9 x 12.9 x 9.3 in.)	
Weight	9 kg (20 lb), excluding accessories case	
POWER REQUIREMENTS	Nominal input voltage range: 115-230 V AC Input voltage range: 90-264 V AC AC frequency range: 47-63 Hz Watts: 40 W	
Battery	Panasonic CR2450 lithium coin cell 3 V 620 mAh	
Fuse ^{*5}	6.3 A, 250 V, 5 x 20 mm	
TECHNOLOGY		
LCD Size	6.5 in. color touchscreen	
LCD Type	Resistive touchscreen	
Screen Resolution	640 x 480	
Computer Interface	USB	
Digital output	CSV file format	
Hardcopy output	58 mm thermal panel printer	

^{*1}Note: Parameters specified in application with mineral oil.

*² Note: Accuracy is quoted for the detectors under factory calibration and test levels. Gas-in-oil measurements may be affected by sampling, oil type, environmental conditions and/or product usage cycle.

*³ Note: Whichever is greater.

*⁴ Note: Given in ppm.

*⁵ Note: Use only the approved and recommended fuse to ensure continued fire protection and compliance.

*⁶ Note: Laboratory results can vary greatly worldwide as has been established through many round-robin tests. Any comparison of product measurement results against laboratory results need to be considered in this context.

4 COMPLIANCE

The product is designed to meet the following type tests as listed in Table 4-1.

Table 4-1: Type tests

CATEGORY	STANDARD	CLASS/LEVEL	TEST
EMC Emissions EN 61326-1:2013	CISPR 11	A	Radiated & Conducted Emissions
	FCC Part 15	Meets the requirements of A	Radiated & Conducted Emissions
EMC Immunity EN 61326-1:2013	EN 61000-4-2	IV 8 kV contact, 15 kV air	Electrostatic Discharge
	EN 61000-4-3	III – 10 V/m	Electromagnetic Field Immunity
	EN 61000-4-4	III – 2 kV, 4 kV	Electrical Fast Transients
	EN 61000-4-5	III – 1 kV, 2 kV, 4 kV	Surge Immunity
	EN 61000-4-6	III – 10 V	Conducted RF Immunity
	EN 61000-4-8	IV & V – 30 A/m, 100 A/m, 1000 A/m	Magnetic Field Immunity
	EN 61000-4-11	III – 0%, 40%, 70%	Voltage Dips & Interruptions
Environmental	IEC 60068-2-1	5 °C	Cold
	IEC 60068-2-2	50 °C	Dry Heat
	IEC 60068-2-30	40 °C, 95% RH	Damp Heat
	EN 60529	IP20 Open	Degree of Protection
		IP67 Closed	
Safety	IEC/EN 61010-1		2010

5 EQUIPMENT

5.1 Overview

The product contains an embedded computer, firmware and various software algorithms to assist in the diagnosis of electrical equipment. The embedded computer has an HMI touchscreen interface to guide the operator through the operation of the system and an internal storage capacity for over 20,000 records. A 58 mm thermal printer is also incorporated within the product design, enabling the operator to maintain hard copy records of all tested samples (see Section 5.3). The USB connection allows communication with an external computer allowing databases to be downloaded to a PC and then shared as required.

The accessories case includes a sample bottle with connections and pipes, and a syringe for extracting a 50 ml oil sample from the equipment being monitored and injecting it directly into the bottle (see Sections 5.4 and 7.3.3). The target gases are extracted from the oil sample using a highly stable headspace equilibrium extraction method and are then measured using infrared photo-acoustic spectroscopy (but a semiconductor sensor is used for measuring hydrogen, see Section 10.5). The moisture is measured directly in the oil phase using a capacitive sensor. The product can also test gas samples taken from a Buchholz relay, although with reduced accuracy due to a very large dilution factor, see Section 9). The wide dynamic range of measurement of the product means it is also very suitable for testing tap-changer and circuit-breaker oil.

It is recommended to analyze the sample as soon as practically possible after extraction, to minimize any risk of contamination or degradation of the oil sample over time. GE provides a ground-glass syringe with the product, which can be used for reliable sample storage for several days if kept out of direct sunlight and extremes of temperature.

The following items are also available to purchase as optional extras:

- A Buchholz Kit (KITT00005) for the collection and analysis of Buchholz gas samples (see Section 9).
- A System Check Kit (KITT00002) to verify the calibration accuracy of the product using a canister of sample gas (see Section 10).
- A Transit case for extra protection during air travel and/or harsh environment transportation (meets IP67 when closed), and can accommodate the unit and up to two accessories cases.
- A Cooler box for storing and cooling hot oil samples for immediate analysis. This can also be used as a secure transportation container for the sample.
- An additional Accessories case (in case of contamination, breakages/damage or loss of items).



Figure 5-1: Transport X² in operation

5.2 Accessories Kit

The product is supplied with a range of accessories and replacement spare parts as listed in Table 5-1.

Table 5-1: Accessories Kit

Item	Description
1	50 ml ground glass syringe
1	Three-way plastic stopcock (for use with the syringe)
1	Sample bottle & lid assembly Note: This must be kept with the unit.
1	Spare sample bottle
1	Magnet retriever
1	Quick connection valve (for oil injection from the syringe)
2	Teflon-coated stir bars
8	Replacement Teflon filters
1	USB Cable
1	115 or 230 V power cable

All the accessories are supplied in a light carry case with protective foam inserts (see Figure 5-2).

Note: Every Transport X² unit is paired with a specific accessory case that shares the same serial number as the unit with which it shipped. They should be stored together to avoid the bottle lid assembly being used with another Transport X². However, if the lid assembly of another unit shall be used, refer to Section 12 for details on how to register the lid assembly correctly with the device.



Figure 5-2: Accessories Kit

5.3 Thermal Printer

The product is equipped with a 58 mm thermal printer built into the top panel as shown in Figure 5-3 for printing results in the field. The printer has a Status LED indicator that flashes to report faults accordingly e.g. out of paper. To replace the paper roll, carefully pull up the clear plastic cover by the rear-raised edge to release the locking mechanism on the black lid at the front. Lift up the hinged lid to access the paper reservoir and remove any remaining paper. Unroll 5 cm of paper from the new roll and then drop the roll into the reservoir. Ensure the thermo-sensitive side of the paper is orientated correctly for printing. Close the lid by applying equal amounts of pressure on each side to ensure that the lid locks down. Press the white 'Mode' button to engage the paper feed. Tear away the excess paper from either side across the serrated edge.

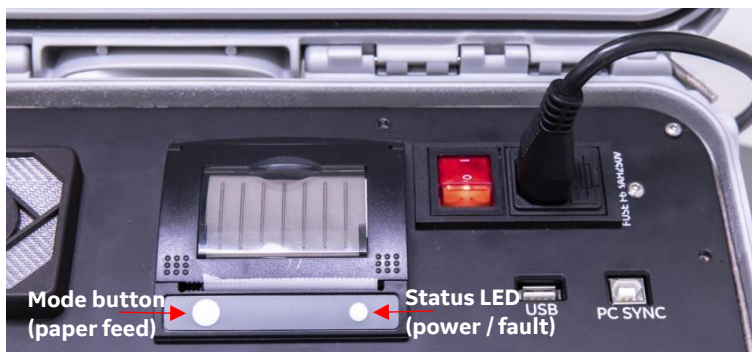


Figure 5-3: Thermal Printer

5.4 Sample Bottle and Connectors

The supplied sample bottle includes a 'lid assembly' as shown in Figure 5-4. Each lid assembly is labelled with unique coefficient parameters. For this reason, the lid assembly is not interchangeable with other Transport X² units unless the parameters have been updated on the unit. The lid assembly incorporates airtight compression fittings and a temperature probe incorporating a capacitive moisture sensor, all of which are to be connected to the top panel of the product. These gas connectors are of the simple 'snap-in' variety, but are 'polarized' so that only one order of connection of the input and return is possible. Operators must ensure that these connections are fully made when using the product.

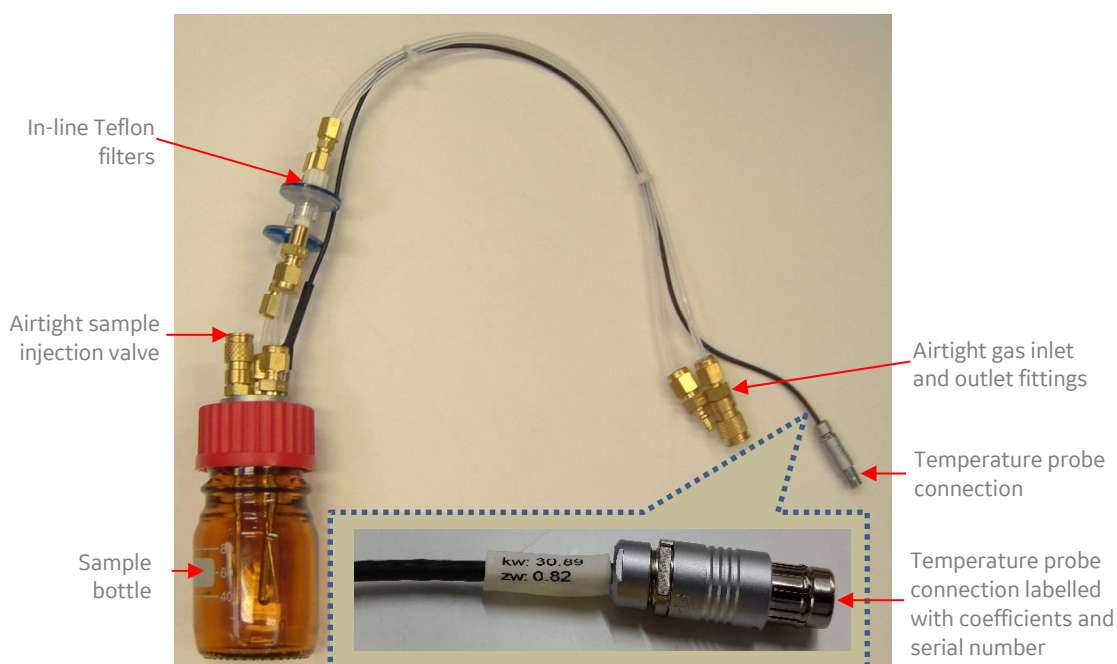


Figure 5-4: Sample bottle and lid assembly

5.5 Teflon Filters and Stirrers

Two Teflon-coated magnetic stirrers are provided; place one (1) in the bottle before the lid is screwed on during assembly of the pipe work. This magnet is rotated within the bottle during the analysis cycle, and its presence is essential for the accurate operation of the product. The magnetic stir bar should also be wiped clean after each test. The stir bar can be removed from the oil in the bottle using the retriever stick provided.

An in-line Teflon filter is fitted in both the return and inlet gas pipes. Luer lock fittings are used to connect these filters. These fittings allow for quick replacement of the filters at regular intervals or if oil should get into the pipe work by accident, thus blocking the filters. These filters are impervious to oil at operating pressure and function to protect the instrument from oil aerosol, accidental spills and airborne dust. Both these filters must always be present. If a spill occurs and oil makes its way into the gas analysis chamber of the photo-acoustic module, the instrument will require a new spectrometer.



If oil drops are present in the pipes of the lid assembly, do not use the equipment.

It is recommended that the Teflon filters be changed after every 20 samples, but the product will remind the operator to do this. If any oil residue is present in the pipes, or the filters appear discolored, then the filters should be replaced before testing the next sample. Clean the pipes by a compressed air blowout if oil is present in the pipes.

5.6 Preventing Contamination

It is recommended that after first unpacking the product (and periodically whenever time permits), to conduct a 'System Flush' (see Section 7.9.2). This process flushes ambient air through the product for 20 minutes to clear any potential contaminants left from packing materials (or test samples if used previously). This feature is also useful to clear the product of gas after a concentrated gas-in-oil sample e.g. from a load tap changer (LTC).

The product is designed to prevent cross contamination between samples using simple cleaning techniques (see Section 8). Use only a clean dry cloth or tissue to thoroughly clean the bottle after each test. Care should also be taken to prevent any contamination from the syringe, probes, stirrer and lid assembly pipes. It is important to ensure there is no residue of oil left in the oil injection port of the lid assembly or the valve connections of the syringe, as this could cause contamination of the next sample to be tested. Remove any trapped oil at these locations using a syringe filled with normal ambient air as outlined in Section 8.2. This ensures that no unwanted residue of oil remains from a previous sample.

When the sample bottle contains oil, it is essential that it be kept upright and not inverted or placed in storage on its side to avoid ingress of oil into the pipework. Dispose of the oil as soon as the sample has been tested as outlined in Section 2.4 to minimize the risk of accidental contamination.

5.7 Operating Environment

It is a requirement that the local environment where testing is conducted be free from excessive atmospheric pollutants and excesses of temperature or pressure as per the operation of any gas analysis equipment. Details of these temperature and pressure ranges are provided in the Technical Specifications (see Section 3).

The internal detector of the product is sensitive to the DGA gases and it is this sensitivity that allows the product to report ppm values for each of the seven diagnostic gases. The product uses the local atmospheric air when extracting the gases from the oil. Therefore, it is important that the ambient air must be free of any target gases, since a gas above a certain tolerance can reduce the product's sensitivity to gas-in-oil and affect the measurement accuracy.

Steps have been taken to reduce this sensitivity and the product will report if it detects a gas in the ambient air that is above a certain threshold. This will be in the form of an error report during product setup or following completion of the analysis. If a local ambient condition is outside the required tolerance for the product, the software will offer

suggestions as to action the operator can take to minimize the effect of this contamination (see Section 7.6).

Ideally, the product should be used in clean, outdoor or filtered indoor air, away from smoke, chemicals, solvents or any source of gas, such as open containers of insulating oil to avoid any possible contamination issues.

5.8 Key Usage Points

Observe the following points to ensure correct use of the product:

- Read and follow all onscreen instructions.
- Always use 50 ml samples of oil.
- Always use a clean syringe, lid assembly and bottle (see Section 5.6 and Section 8).
- Do not use solvents to clean any of the apparatus or accessories.
- Place one magnetic stirrer piece in the bottle for the sample to be analysed correctly (required only for oil samples).
- Following oil injection into the sample bottle, the bottle must not be moved until the analysis is complete. If the bottle is moved, the results would be adversely affected since the magnetic stirrer would not operate as expected.
- When the sample bottle contains oil, it must be kept upright to avoid ingress of oil into the pipe work of the lid assembly.
- Ensure that the pipes' quick connect fittings are connected correctly and securely, as per instructions.
- When the sample bottle is removed, the bottle lid assembly should be held upright and then cleaned carefully with a cloth or tissue after use and before storage to avoid any ingress of oil into the pipe work (see Section 8).
- Always empty the sample bottle waste oil after a test is completed. Also, clean the apparatus immediately after every test (see Section 8).
- The 'purge time' can be increased (maximum 10 minutes) to help prevent carry-over from a heavily gassed sample to the next sample. It is recommended that the maximum time be used where available time permits.
- If the product is unpacked from new or storage, the operator should run a 'System Flush' operation to help clear the gas paths from potential contamination from any packing material/gas effluents (see Section 7.9.2).
- It is recommended to perform a full measurement cycle or dry run at least once a month to maintain operational rigor. Such dry runs can be performed with or without injecting an actual sample. Furthermore, it is recommended to run the Leak (Pressure) test as part of this exercise (see Section 7.9.3).

6 OIL SAMPLING

Correct sampling of the insulating oil is essential to obtain a representative sample from the equipment. The sample must be ready for injection into the Transport X² without risk of any contamination, pre- or post- sampling, to ensure an accurate snapshot of the overall condition of the oil within the equipment.

The oil sampling procedure described here is based on the international standard IEC 567 (addresses oil sampling from oil-filled electrical equipment for the analysis of dissolved gas) and is supplemented with several apparatus-specific images. The procedure assumes that there is an available fitting on the equipment that allows connection of a two-way Luer lock valve, either in-line in a sampling pipe, or as a fitting that can be connected directly to the sampling point. Many different configurations are possible, but the requirement is the same for all.

The sample container consists of a 50 ml ground-glass syringe to which a two-way plastic stopcock is connected. Although this stopcock is removable from the syringe, for this sampling description, it should be considered as part of the syringe/sample container assembly.

Follow this step-by-step procedure:

1. Connect the syringe via a Luer lock three-way valve to the equipment sampling line.
2. Turn the valve in the equipment sampling line and the valve on the syringe to allow equipment oil to flow out to a waste container from the syringe valve as shown in Figure 6-1. Allow at least 1 litre of oil to flow into a waste container.

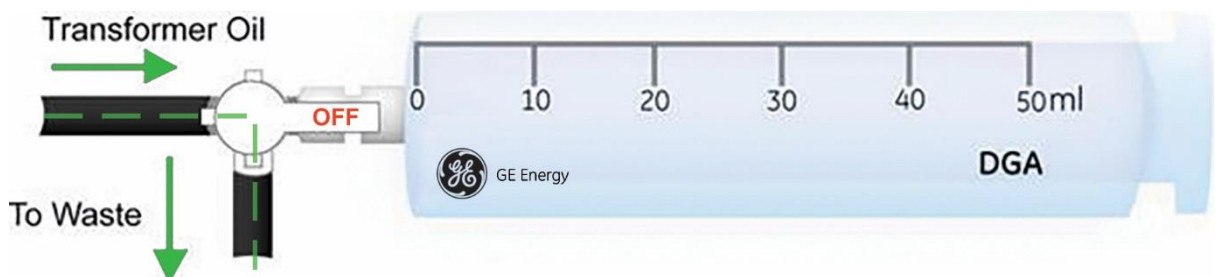


Figure 6-1: Oil flows to waste container

3. Turn the syringe valve to the position where oil can be drawn into the syringe as shown in Figure 6-2.
4. Gently draw oil fully into the syringe body. At this stage bubbles of air from the dead volume in the neck of the syringe are drawn into the syringe body and some of the gas present is dissolved into the oil. Also, some of the gas in the oil escapes into the air bubbles. This oil and gas must be rejected as unrepresentative of the oil in the transformer.

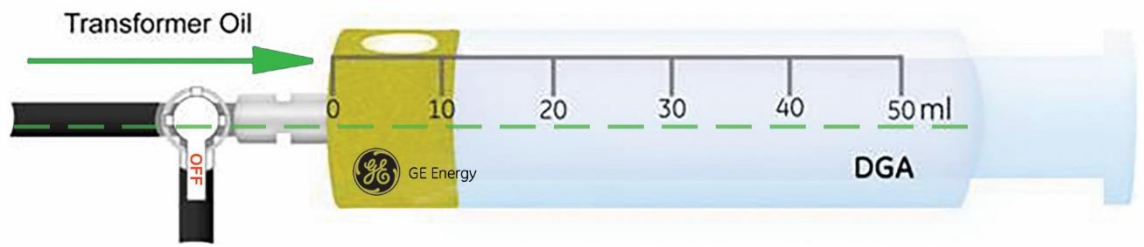


Figure 6-2: Oil flows into the syringe

5. Turn the Luer lock valve fitted to the equipment sampling line to allow oil to flow out from the syringe to a waste container as shown in Figure 6-3.

Note: Hold the syringe upright to expel all the bubbles and most of the oil from the syringe.

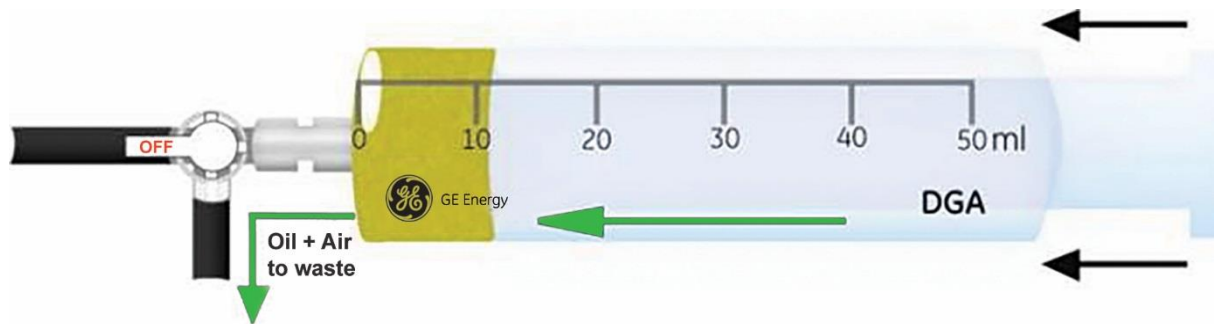


Figure 6-3: Expel oil and air from the syringe

6. Close the syringe valve when most of the oil has been expelled, leaving approximately 2 ml of oil remaining in the syringe.
7. Turn the syringe valve to permit the gentle drawing of 50 ml of oil into the syringe as shown in Figure 6-4.

Note: The head pressure from the transformer main tank may push the oil into the syringe, so care must be taken that it does completely push the plunger out of the syringe body.

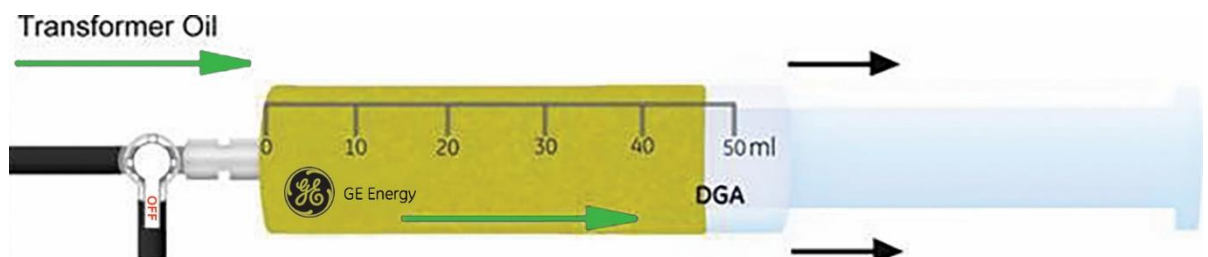


Figure 6-4: Draw oil into the syringe

8. Flush this oil out of the syringe into the waste container as described previously.
9. Repeat Steps 7 & 8 at least twice.
10. Draw exactly 50 ml of oil into the syringe.
11. Turn the equipment valve to prevent any further oil escaping from the transformer.
12. Turn the syringe valve to the fully closed position.

13. Disconnect the syringe from the equipment sampling line.

A representative sample of oil from the equipment is now ready for testing with the Transport X² (see Section 7.3).

Note: If the sample is not tested immediately after being taken, it is recommended to store the sample in a dark, cool place, at normal room temperature.

Note: It is important that the sample is handled correctly to ensure reliable results during measurement. Problems with sampling, storing or injecting the oil sample can all affect results.

7 SOFTWARE OPERATIONS

The product offers step-by-step instructions via the integrated onscreen display and is designed to be easy to use in the field.

Note: Operational details can vary depending on the type of sample. See Section 9 for the procedure relating to gas samples from Buchholz relays.

Note: A hardcopy instruction card can also be found in the lid of the product case.

7.1 Power On/Off

It is recommended to power up the product for 20 minutes to let it reach an optimal operating temperature prior to the first sample injection.

Note: All functionality, including 'oil sampling' and 'system flush' can still be performed immediately from powerup if required.

The product is powered by mains-supplied electricity or a suitable AC supply from a DC inverter. To connect the product to the mains supply, use the IEC cable supplied with the product. When the product is connected to the mains, switch the power on using the red rocker power switch at the top right of the panel.

The integrated computer displays the following splash screen as shown in Figure 7-1 while it boots (which may take 20 seconds or more).

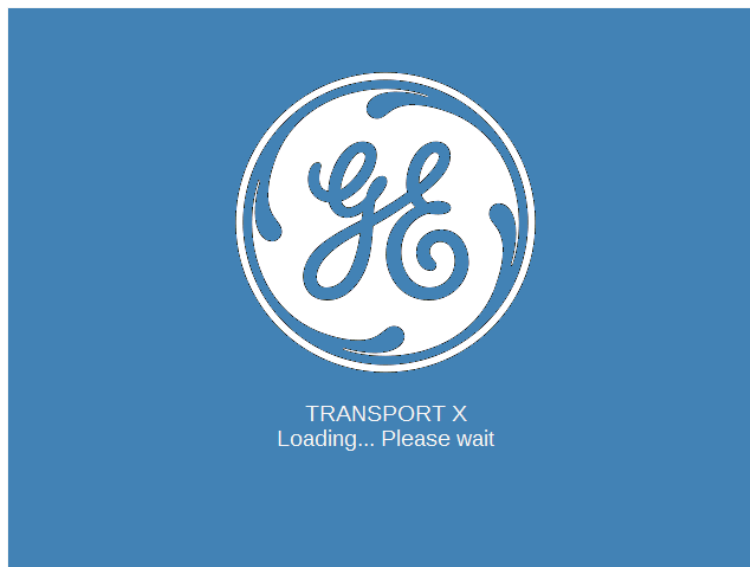


Figure 7-1: Loading splash screen

On a successful boot, the touchscreen opens on the HMI Main Menu as shown in Figure 7-2.

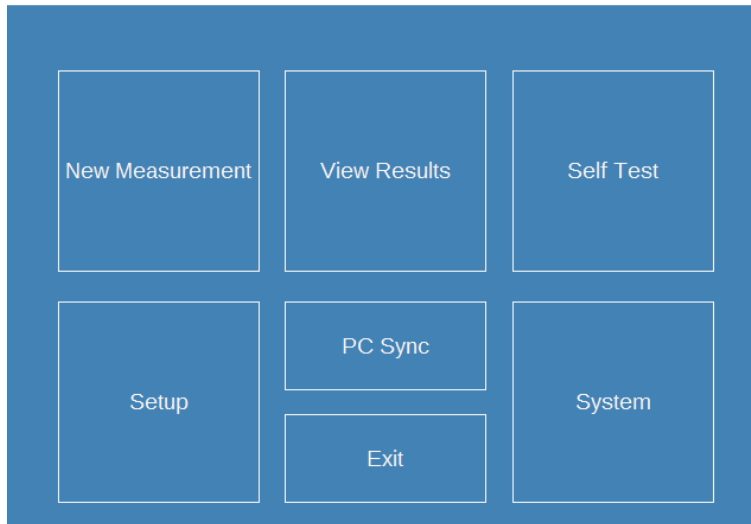


Figure 7-2: Main Menu

To power off the product, press **Exit**. The system will then advise when it is ready to be physically switched off as shown in Figure 7-3. Use the red rocker power switch at the top right of the front panel to switch off the mains supply. Disconnect from the mains supply and store appropriately when not in use.



Figure 7-3: Switch off

Note: It is *not* recommended to turn off the product directly at the power switch or mains supply without first following the above shutdown procedure.

7.2 Main Menu

The instructions displayed on the touchscreen are used to control the operation of the product. The Main Menu screen provides seven options as shown in Figure 7-4:

- New Measurement: See Section 7.3 on page 26.
- View Results: See Section 7.4 on page 43.
- Self Test: See Section 7.8 on page 71.
- Setup: See Section 7.7 on page 67.

- PC Sync: used for downloading measurement data to the Perception software suite (see Appendix B). PC Sync is also used to do a full data backup (including system log files) to a USB pen drive (See Section 11 on page 94).
- Exit: See Section 7.1 on page 24.
- System: See Section 7.8 on page 71.

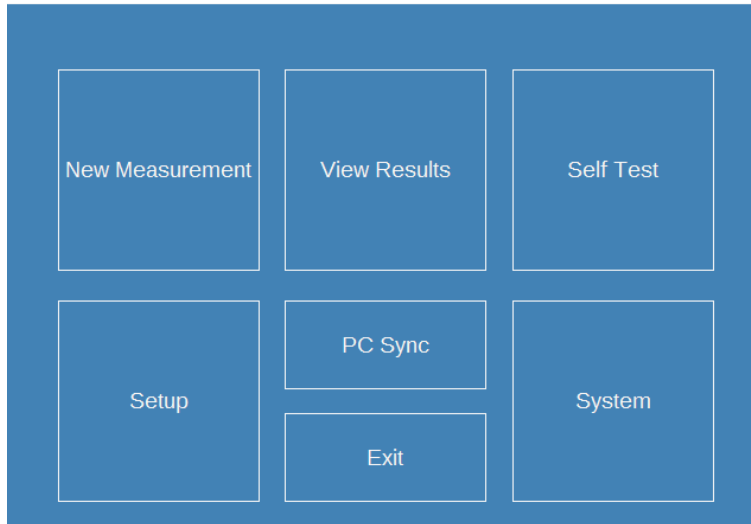


Figure 7-4: Main Menu

7.3 New Measurement

The product walks the operator through the process of creating a site measurement record, prompting for information when required and adding an appropriate date stamp in the product's database. It is important to supply accurate information when creating a new record as it will make it easier to search for results later.

7.3.1 Input Record

From the Main Menu, press **New Measurement** as shown in Figure 7-5.

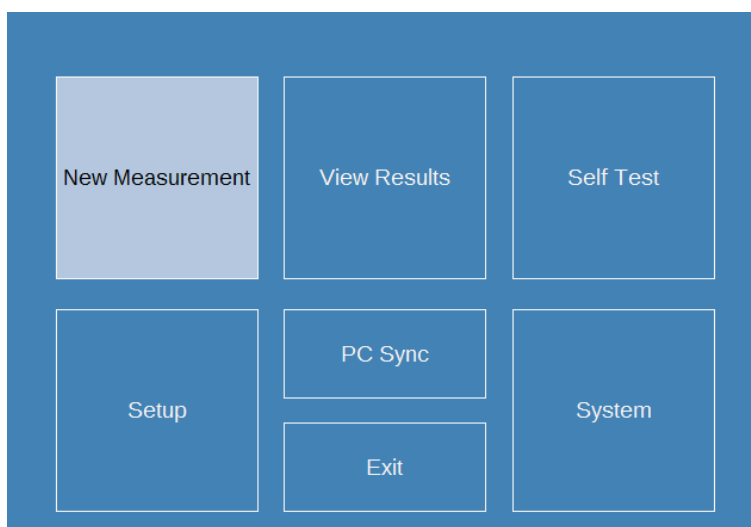


Figure 7-5: New Measurement

The Equipment Type screen displays as shown in Figure 7-6. Select the type of equipment to be analyzed and press **Next**.

Note: The default or currently selected item is shown in red.

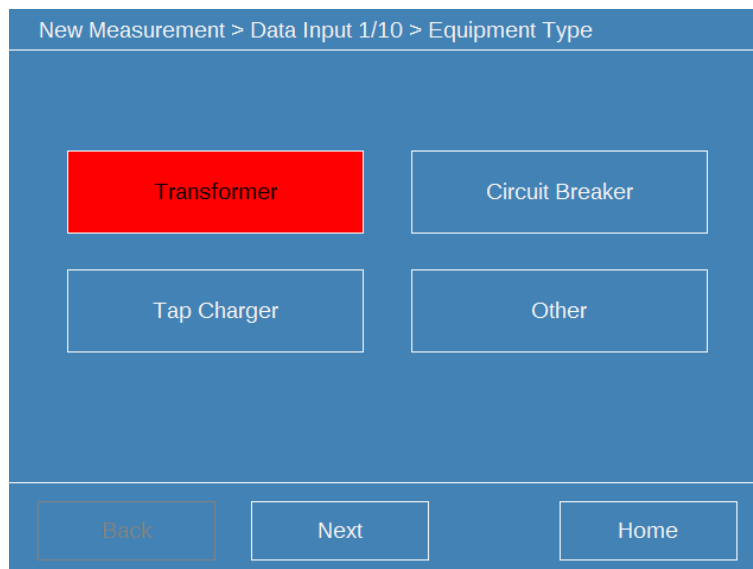


Figure 7-6: New Measurement > Data Input (step 1/10) > Equipment Type

The Location screen displays as shown in Figure 7-7.

If the location already exists in the database from a previous test, select the location from the existing list. If the correct location does not already exist in the database, press **Add New** or press **Edit** to modify an existing location.

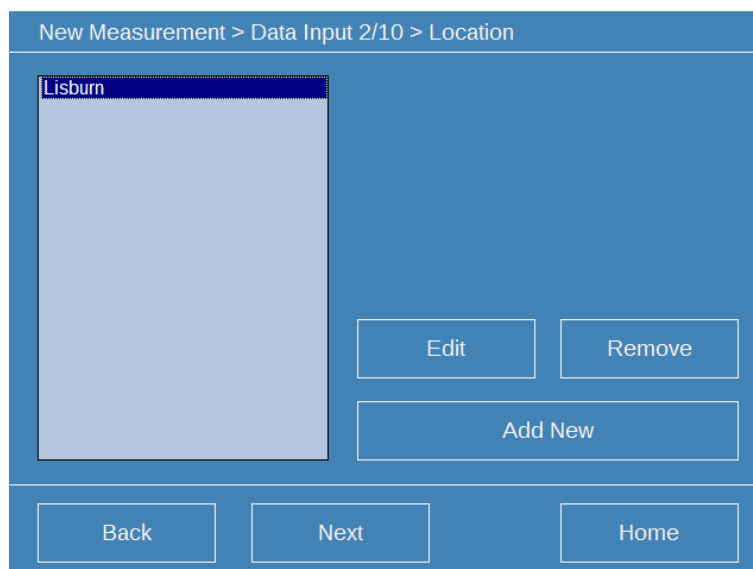


Figure 7-7: New Measurement > Data Input (step 2/10) > Location

If adding or editing a location, the display changes to a touchscreen keyboard as shown in Figure 7-8. Type the correct Equipment Location details and press **OK** to create the record in the database.

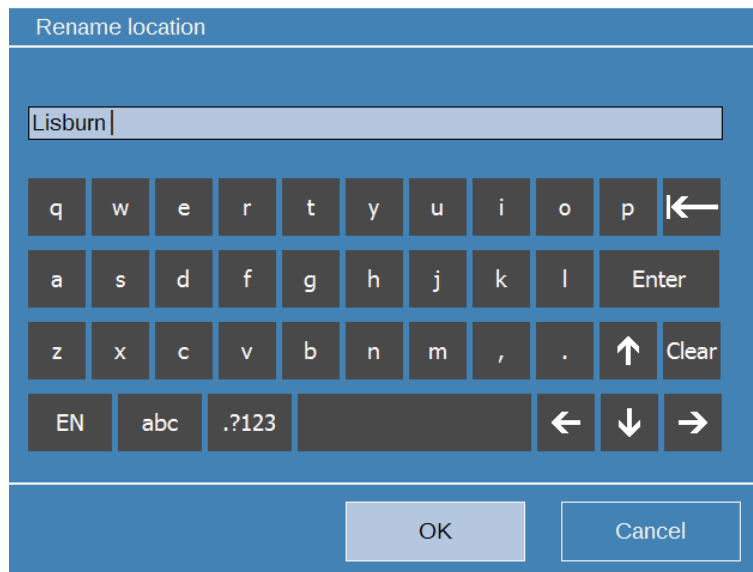


Figure 7-8: New Measurement > Data Input (step 2/10) > Location – keyboard

Once the correct location is selected, press **Next** to continue as shown in Figure 7-9.

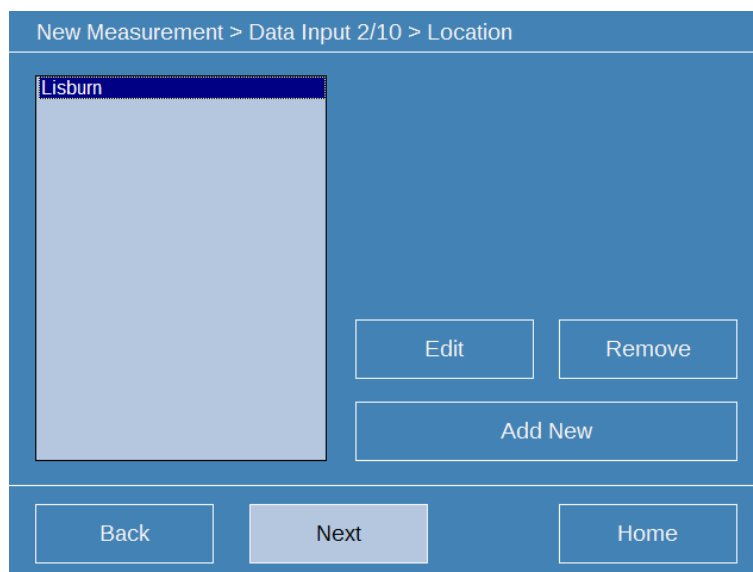


Figure 7-9: New Measurement > Data Input (step 2/10) > Location

The Equipment screen displays as shown in Figure 7-10. If the equipment already exists in the database from a previous test, select the correct equipment from the existing list.

If the correct equipment does not already exist in the database, press **Add New** or press **Edit** to modify an existing item. The display changes to an onscreen keyboard.

Once the correct equipment is selected, press **Next** to continue.

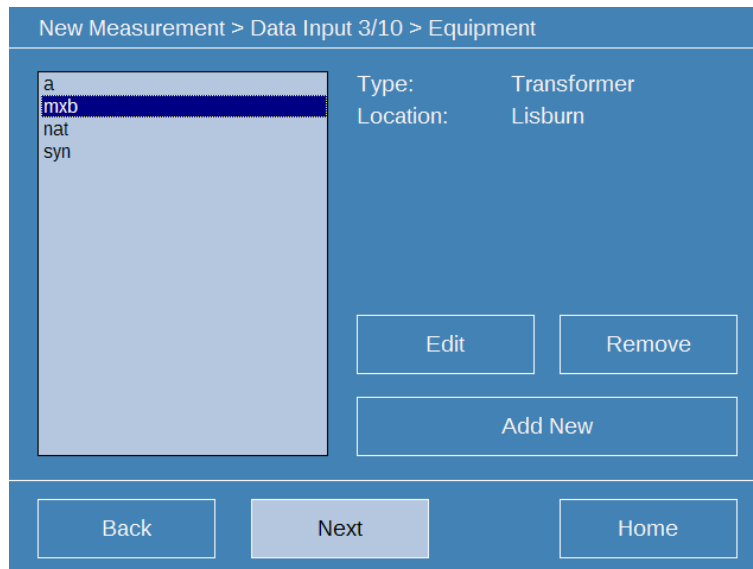


Figure 7-10: New Measurement > Data Input (step 3/10) > Equipment

The Sampling Point screen displays as shown in Figure 7-11. If the sampling point already exists in the database from a previous test, select the sampling point from the existing list.

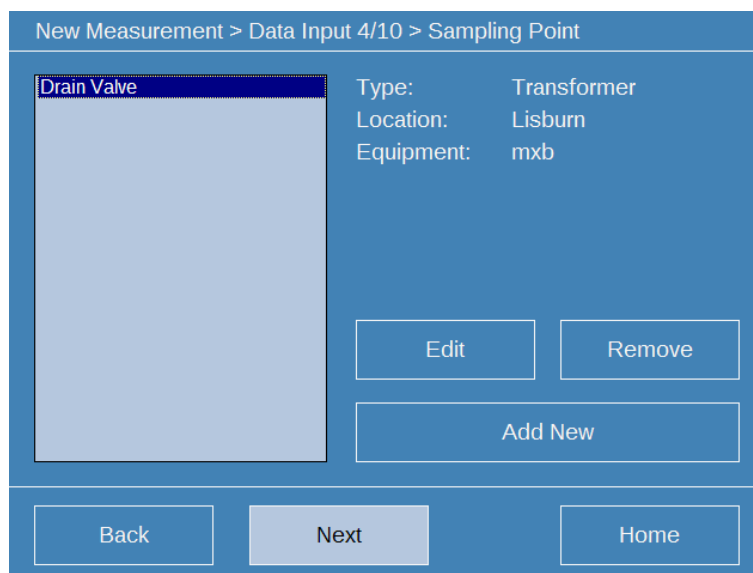


Figure 7-11: New Measurement > Data Input (step 4/10) > Sampling Point

If the correct sampling point does not already exist in the database, press **Add New** or press **Edit** to modify an existing item. The display changes to an onscreen keyboard.

Once the correct sampling point is selected, press **Next** to continue.

The Manufacturer screen displays as shown in Figure 7-12. If the Manufacturer already exists in the database from a previous test, select the manufacturer from the existing list.

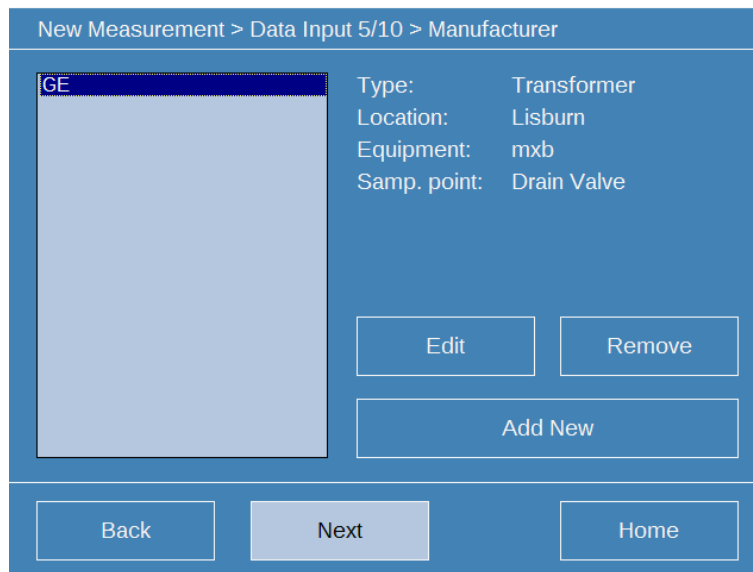


Figure 7-12: New Measurement > Data Input (step 5/10) > Manufacturer

If the correct manufacturer does not already exist in the database, press **Add New** or press **Edit** to modify an existing item. The display changes to a touchscreen keyboard.

Once the correct manufacturer is selected, press **Next** to continue.

The Manufacturer Model screen displays as shown in Figure 7-13. If the model already exists in the database from a previous test, select the model from the existing list.

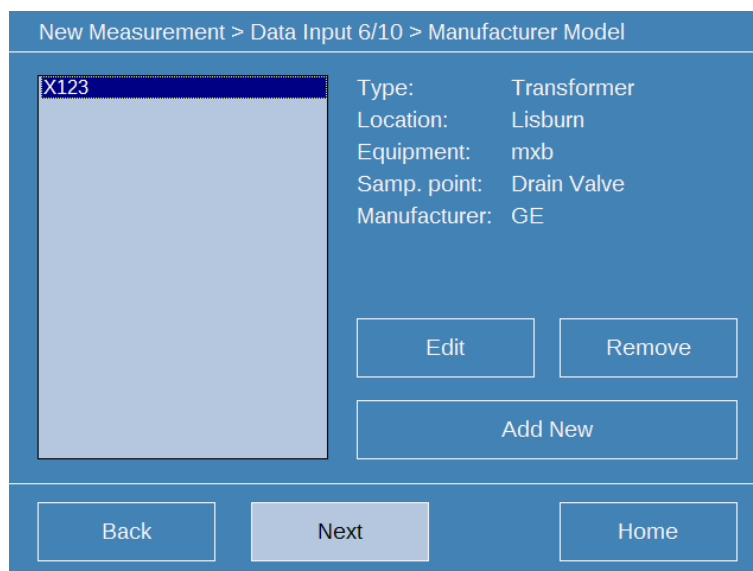


Figure 7-13: New Measurement > Data Input (step 6/10) > Model

If the correct model does not already exist in the database, press **Add New** or press **Edit** to modify an existing item. The display changes to a touchscreen keyboard.

Once the correct model is selected, press **Next** to continue.

The Serial Number screen displays as shown in Figure 7-14. If the serial number of the transformer or equipment already exists in the database from a previous test, select that serial number from the existing list.

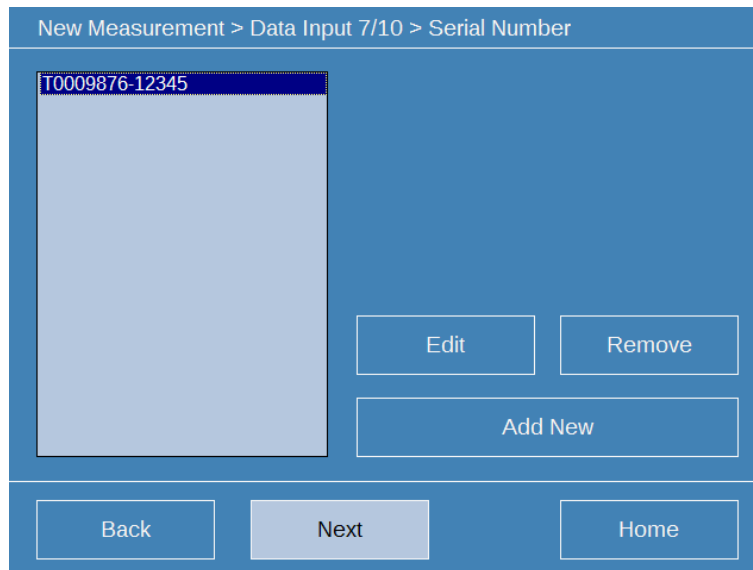


Figure 7-14: New Measurement > Data Input (step 7/10) > Serial

If the correct serial number does not already exist in the database, press **Add New** or press **Edit** to modify an existing item. The display changes to an onscreen keyboard.

Once the correct serial number is selected, press **Next** to continue.

The Sample Details screen displays as shown in Figure 7-15. The operator is required to provide details of the source of the sample.

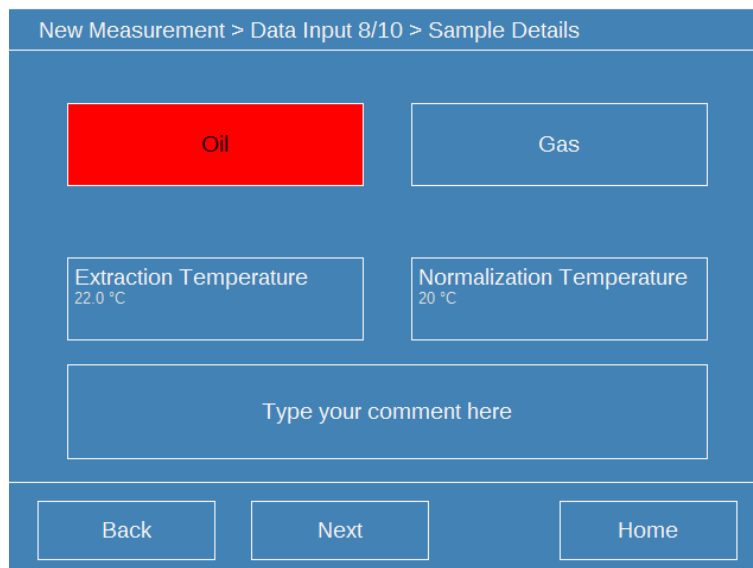


Figure 7-15: New Measurement > Data Input (step 8/10) > Sample Details

The Sample Details screen provides two source options:

- The default (in red) is **Oil**;
- But if the sample is gas, from the Buchholz relay, then select **Gas**. See Section 9 for details regarding the sampling and analysis of gases from gas-collecting (Buchholz) relays.

And other optional details:

- **Extraction temperature:** Use this option to set the oil sampling temperature (in degrees Celsius), i.e. the temperature of the oil at the time it was sampled as displayed on the transformer temperature gauge or similar. This is used to calculate the percentage Relative Saturation (RS) of the sample. **Note: If the temperature is not added, then the results will not include an RS figure.**
- **Normalization temperature:** Use this option to normalize the DGA concentration results (measured in ppm) to a specific temperature. The default temperature is 20 °C.
- **Type your comment here:** free text for optional comments. This is useful for recording additional information about a sample or piece of equipment.

Press **Next** to continue.

The Oil Type screen displays as shown in Figure 7-16. The product can test mineral oil or ester-based fluid (natural or synthetic).

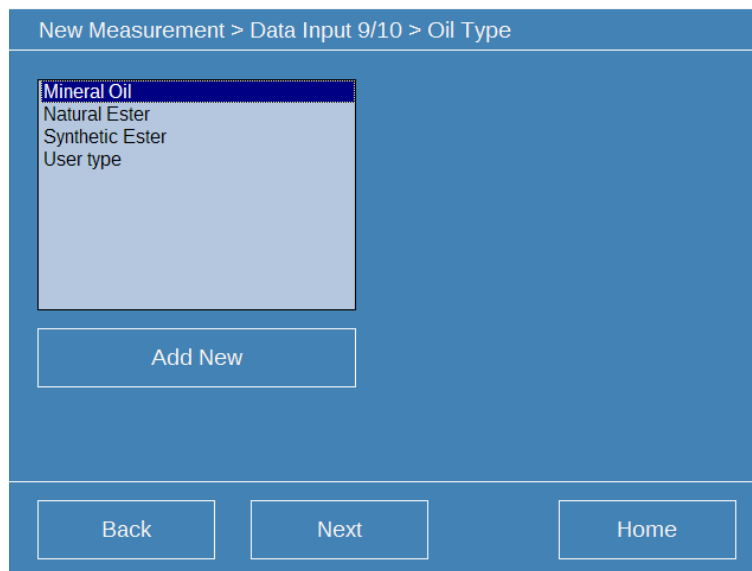


Figure 7-16: New Measurement > Data Input (step 9/10) > Oil Type

Select the type of oil and press **Next**.

The Gas Limits screen displays as shown in Figure 7-17 with a list of 'gas limit names' on the left and the collection of gases with corresponding 'Caution' and 'Warning' Gas Limits values to the right.

Note: 'default' is the initial Gas Limit name for the default collection of Gas Limits values.

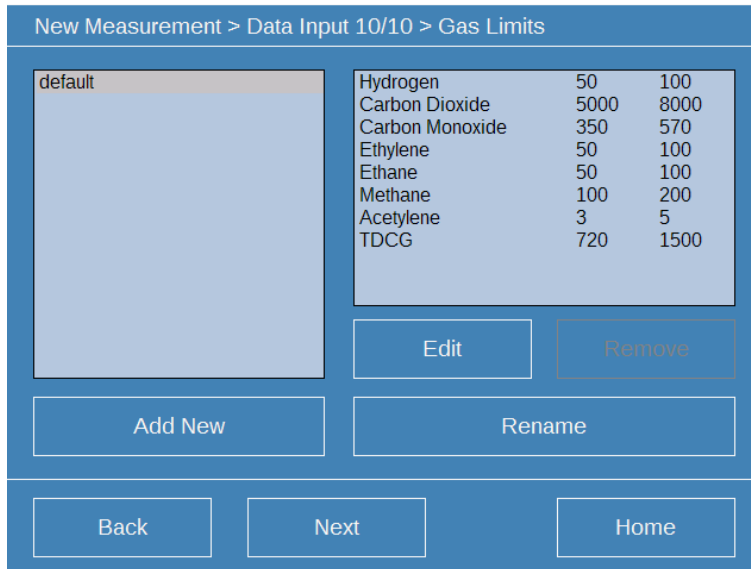


Figure 7-17: New Measurement > Data Input (step 10/10) > Gas Limits – names

If the 'Gas Limits name' already exists in the database from a previous test, select the 'Gas Limits name' from the existing list on the left.

Options exist to edit an existing set of Gas Limits, add another set of Gas Limits using a new name, rename an existing set of Gas Limits or remove an existing set of Gas Limits (currently disabled as, in this example, the list contains only the 'default' limit and this cannot be removed).

Note: The 'default' Gas Limits name or list of gases cannot be edited, but the limit values can be modified.

To modify any of the Gas Limits values, select the Gas Limits name and press **Edit**. The display changes to the Gas Limits values screen as shown in Figure 7-18. Here the Caution and Warning PPM limits are set for each gas.

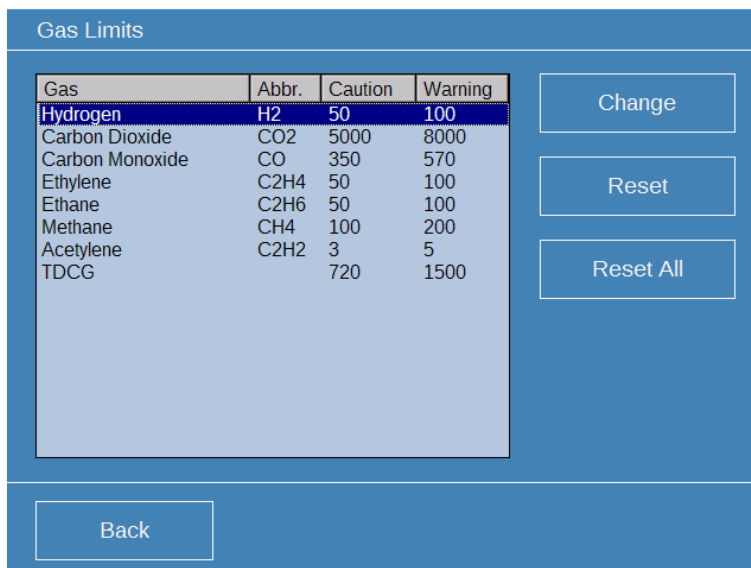


Figure 7-18: New Measurement > Data Input (step 10/10) > Gas Limits – values

It is possible to modify the PPM gas limits for any individual gas, reset individual gas limits to the default setting or reset all gas limits to the default setting. For example, to change the limits for a gas, select the gas and press **Change**.

The Set Gas Limits numeric keypad displays as shown in Figure 7-19.



Figure 7-19: New Measurement > Data Input (step 10/10) > Gas Limits - values - keypad

Use the keypad to modify the 'Caution' or 'Warning' values as shown in Figure 7-20 and press **OK**.

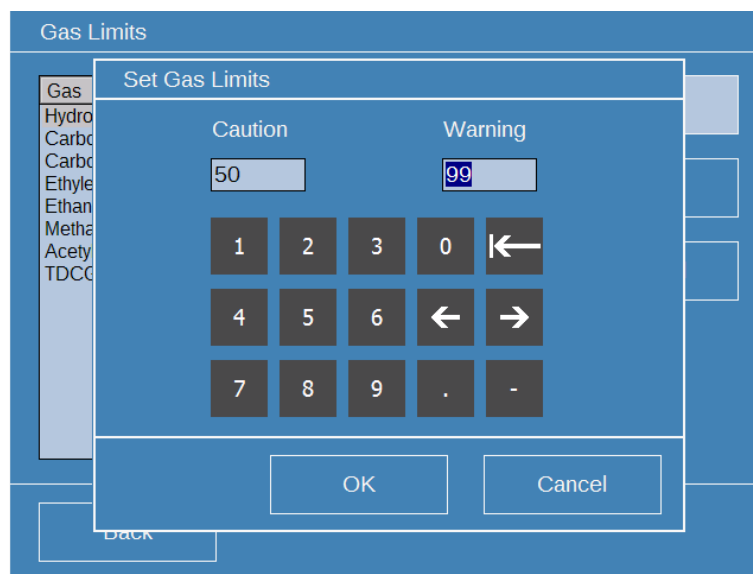


Figure 7-20: New Measurement > Data Input (step 10/10) > Gas Limits - values - keypad - new

The Gas Limits values screen displays with the revised Caution and Warning limits as shown in Figure 7-21. Press **Back**.

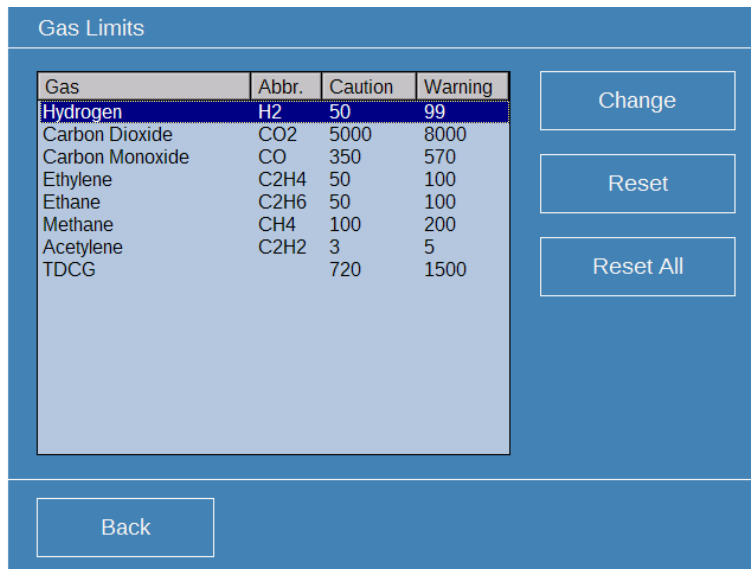


Figure 7-21: New Measurement > Data Input (step 10/10) > Gas Limits – values - new

The 'Gas Limits' screen displays. Select the correct Gas Limits name and press **Next** to continue as shown in Figure 7-22.

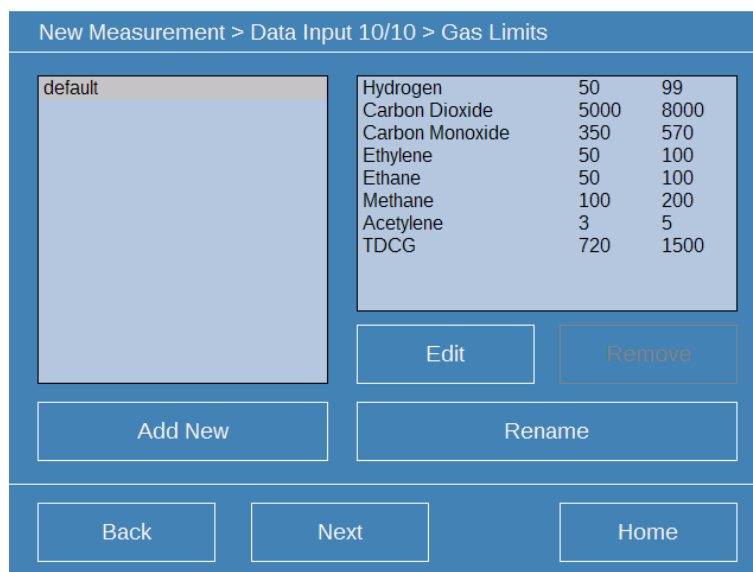


Figure 7-22: New Measurement > Data Input (step 10/10) > Gas Limits – names

The operator should check and confirm all the information that has been entered into the database before continuing.

If any of the details are incorrect, press **Back** to return to the previous sequence of screens and correct the information entered as required. Otherwise press **Next** to continue.

7.3.2 Preparation

When all the sample information has been selected, modified or entered into the database, the software guides the operator through the testing process, beginning with the preparation of the equipment.

The Install Bottle instructions screen displays with the testing instructions as shown in Figure 7-23.

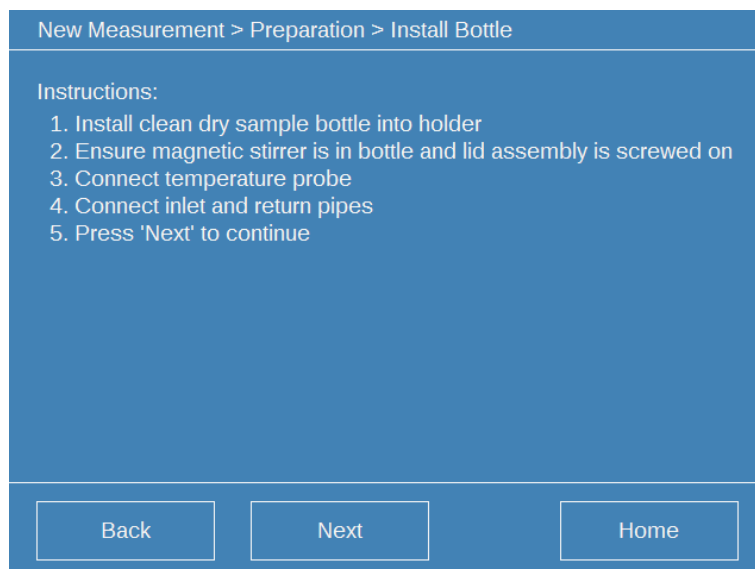


Figure 7-23: New Measurement > Install Bottle - instructions

It is a requirement that a clean dry bottle be used for each test. Following the onscreen instructions, place the empty bottle in the bottle holder cavity and connect the sample bottle to the product as stated in Figure 7-23 and as shown in Figure 5-1 and Figure 5-4.

Press **Next** to begin the testing process.

If the temperature probe is not properly connected, a caution message displays as shown in Figure 7-24. Press **Home** to return to the previous screen.

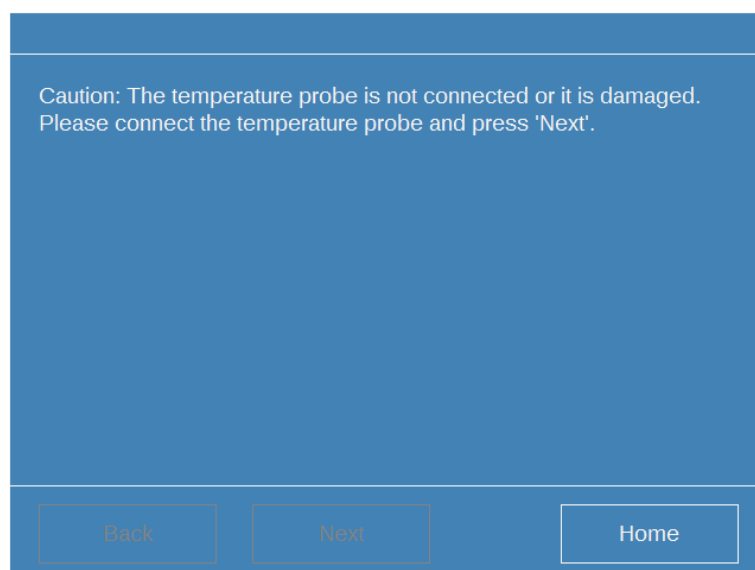


Figure 7-24: New Measurement > Install Bottle > Error

If the bottle temperature probe is connected, the product prompts for a purge time as shown in Figure 7-25, which is typically between 5 and 10 minutes. To adjust the required purge time, press the 'timebox'.

Note: The default listed time is 5 minutes, but longer purges are recommended to help eliminate contamination from previous samples that were heavily-gassed, for example, from Tap Changer oil.

Note: For the default period, the actual duration of the purge is approximately 5 minutes and 40 seconds. If 6 minutes is selected, the actual purge time is 6 minutes.

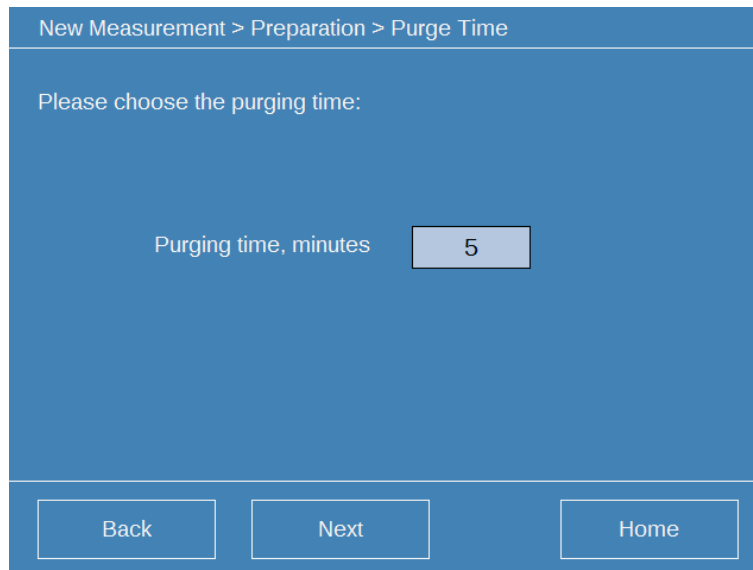


Figure 7-25: New Measurement > Install Bottle > Purge Time

A numeric keypad displays to input the number of minutes as shown in Figure 7-26.

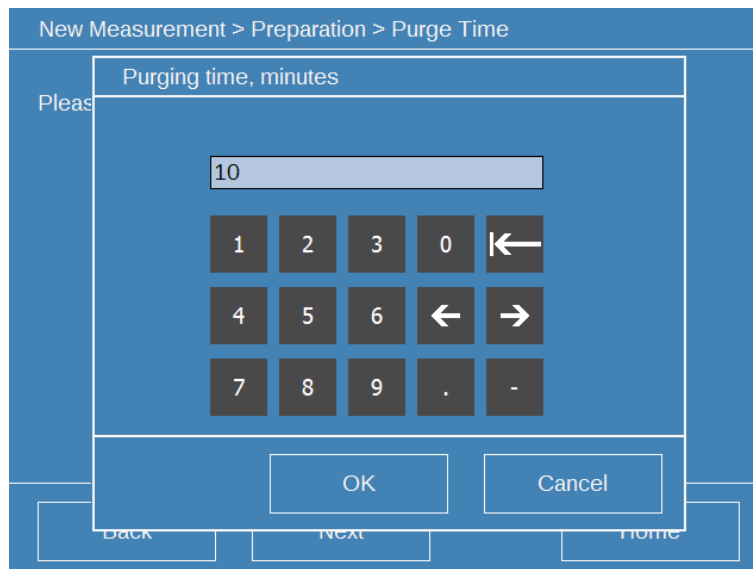


Figure 7-26: New Measurement > Install Bottle > Purge Time - keypad

Type the number of minutes, press **OK** and **Next** to continue.

The Air measurement screen displays as the product prepares for the oil sample as shown by the progress bar in Figure 7-27. The process begins with system venting followed by purging with ambient air. When the purging is complete, the product then automatically measures the gas concentrations in the air of the Transport X² / dry sample bottle combination to provide a zero reference for sample measurements.

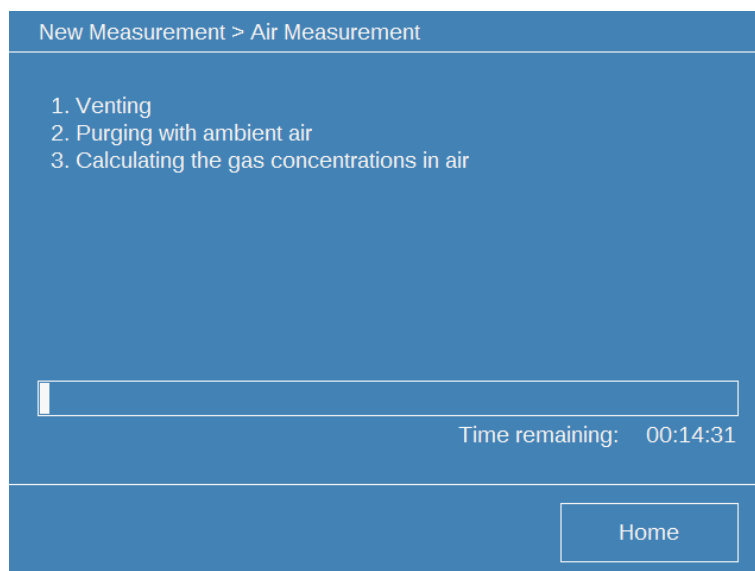


Figure 7-27: New Measurement > Install Bottle > Purge Progress

7.3.3 Injection

Having obtained a representative oil sample as outlined in Section 6 and prepared the product for injection as outlined in Section 7.3.2, follow these steps to inject the sampled oil into the product's sample bottle:

1. Attach the male quick-connect fitting to the syringe's three-way stopcock as shown in Figure 7-28.



Figure 7-28: Male part of the quick-connector valve attached to the syringe

2. Connect the syringe to the sample bottle. The outer sleeve of the female fitting on the lid assembly should be held between the thumb and the forefinger and pressed downwards as far as it will go as shown in Figure 7-29.
3. Insert the male quick-connect fitting that is attached to the syringe firmly into the female connector. A slight click is heard when the connection is fully made. Release the outer sleeve of the female connector to secure the connection.



Figure 7-29: Outer sleeve of the female connector

4. Turn the three-way valve 90 degrees to open the arm from the syringe to the bottle, thus closing the side arm of the valve as shown in Figure 7-30.

Note: If the side arm of the valve is not closed, the oil will escape.



Figure 7-30: Stopcock (three-way valve) with side arm closed

If the oil was hot when the sample was taken, shake the oil sample with a slight positive pressure on the syringe plunger before injecting it into the sample bottle. The reason for this is that it is possible for gas to come out of the solution and form a bubble as the oil cools. By shaking the sample with a slight positive pressure on the syringe, the gas should dissolve back into the oil and the sample should then be ready for measurement.

Once the sample is acceptable, follow the onscreen instructions as shown in Figure 7-31 to inject the oil sample.

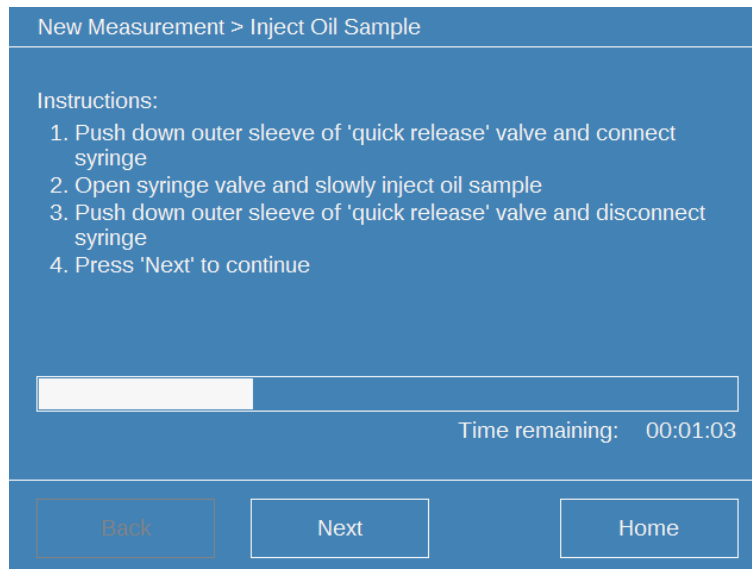


Figure 7-31: New Measurement > Sample Injection - instructions & countdown

The Inject Oil Sample screen displays a progress bar with a countdown. Only 90 seconds are available to complete the injection process.

Note: During this period, the product also emits a beep sound every 5 seconds.

When the oil injection process is complete, press **Next** to initiate measurement before the timeout.

If the process times out, the Sample Injection Timeout screen displays as shown in Figure 7-32. Press **Next** to restart the injection process.

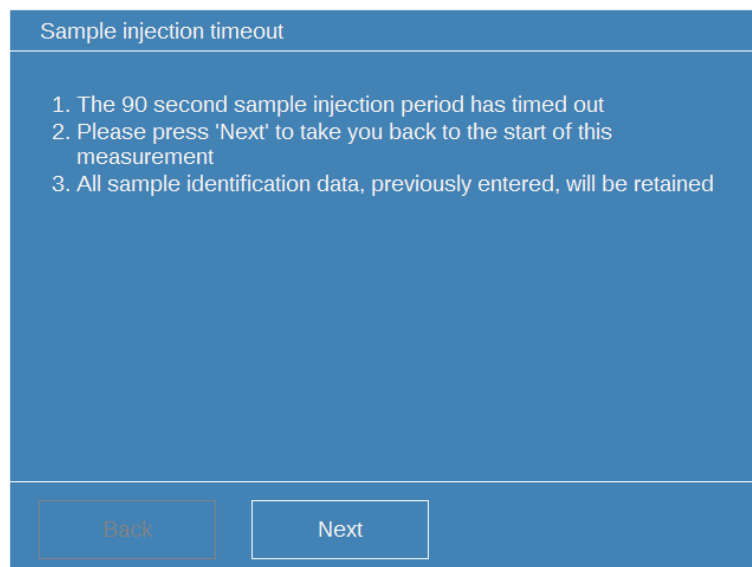


Figure 7-32: New Measurement > Sample Injection - timeout

5. Slowly depress the plunger of the syringe *fully*. When the syringe is fully depressed, maintain gentle downward pressure on the plunger, but wait 3 to 4 seconds before disconnecting the syringe at the quick-release valve.

- To disconnect the syringe, push down on the sleeve of the female section and lift the syringe, three-way valve and male quick-connect assembly away from the female section.

Note: Take care not to separate the male quick-release section from the valve/syringe until the syringe is disconnected from the bottle at the quick-release valve, as that would provide an open channel for the gases to escape to the atmosphere.

Note: Keep the syringe valve open when releasing from the quick connector at the lid assembly as otherwise a pressure difference may be created which may make it hard to disconnect.

7.3.4 Measurement

Prior to performing measurements, the product conducts a temperature check of the sampled oil in the bottle relative to the product. If the product has been stored at a cold location prior to use, it is recommended to allow the product to reach an optimal operating temperature *before* commencing measurement activity (20 minutes from powerup is suggested).

Note: Without a temperature check, condensation could form on the internal pipework as the oil cools, which would affect results.

The temperature check takes 90 seconds. If the oil temperature is higher than the internal cell temperature, measurements are delayed until they are equal. The important criterion is that the product's analysis cell be warmer than the sampled oil.

The screen displays the temperature differential and waits until it reaches 0.0 °C before automatically commencing measurements as shown in Figure 7-33.

Note: Do not touch or remove the bottle from the bottle holder cavity during the temperature check or the measurement phase. If the bottle is not in place, the magnetic stirrer will not operate and the results will be invalid.

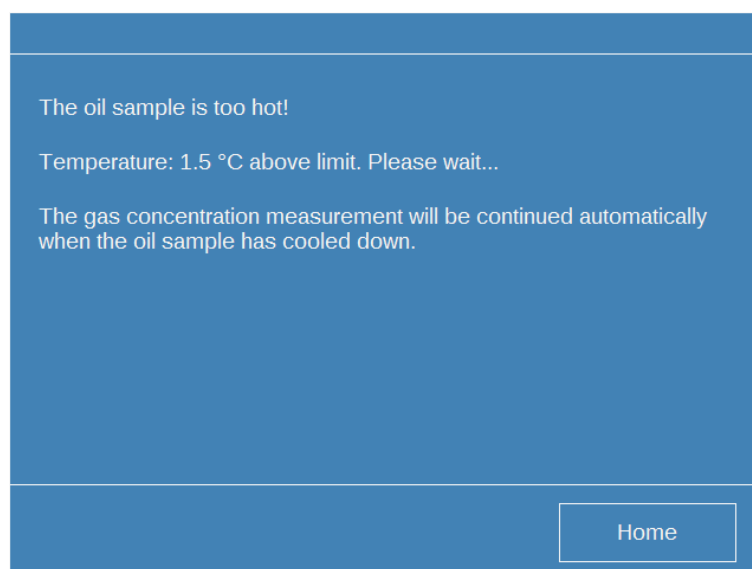


Figure 7-33: New Measurement > Sample Temperature Check

If the oil temperature is acceptable, the product begins the process of measuring the moisture and dissolved gases in the oil sample.

Note: Measurements take approximately 22 minutes to complete.

The Sample Measurement progress screen displays as shown in Figure 7-34.

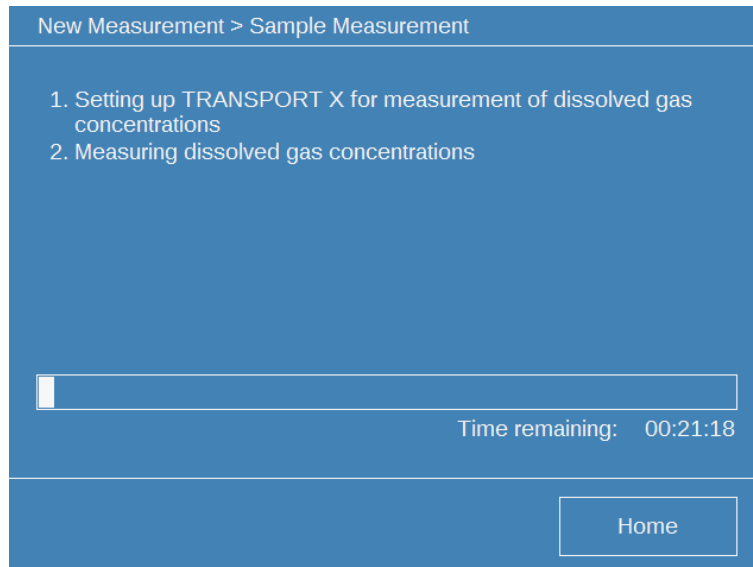


Figure 7-34: New Measurement > Sample Measurement – progress

When the measurements of the oil sample are complete, the results display as shown in Figure 7-35. The Results screen shows the concentration levels of the various dissolved gases and the Total Dissolved Combustible Gas (TDCG) level in the sample oil. The Relative Saturation (RS) percentage is also displayed if the Sample Oil Extraction Temperature (see Figure 7-15) was previously selected as part of the measurement record as outlined in Section 7.3.1.

Note: The Measurement data is automatically saved.

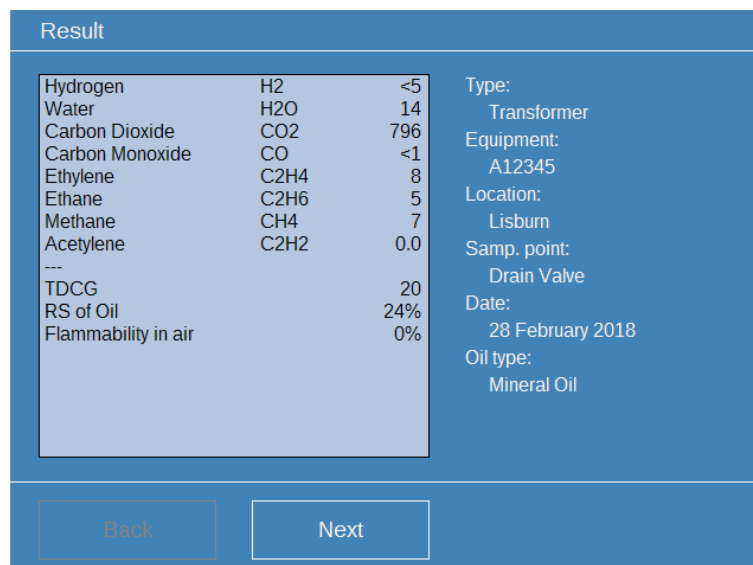


Figure 7-35: New Measurement > Results

Press **Next** to examine the record options as described in Section 7.4 to 7.6 including the Analysis and Diagnostic options outlined in Section 7.5.

The Clean-up screen displays as shown in Figure 7-36. Follow the instructions to disconnect and clean the equipment. See Section 8 for guidance on cleaning.

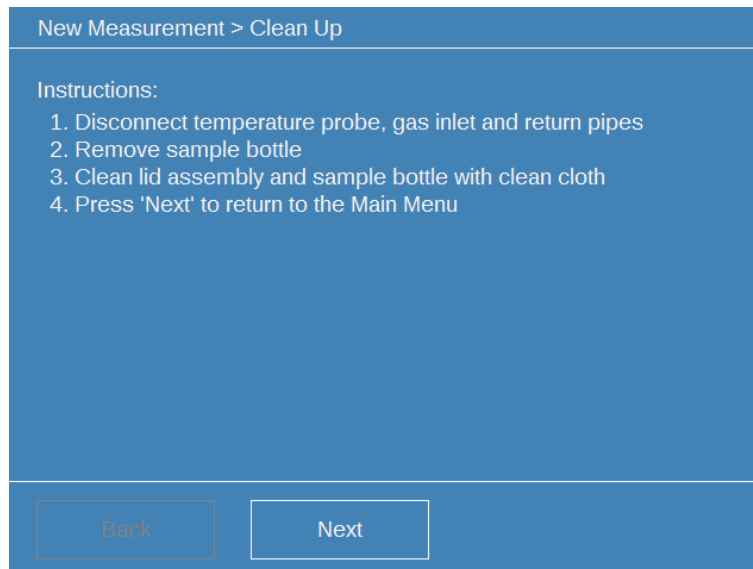


Figure 7-36: New Measurement > Clean-up - instructions

7.4 View Results

The product provides a means of searching the internal database for previous measurement results. In addition to measurement results, the database also stores associative information input by the operator when creating a new measurement record, such as the transformer details (see Section 7.3.1). All this information is searchable.

From the Main Menu screen, press **View Results** to examine the options for retrieving records as shown in Figure 7-37.

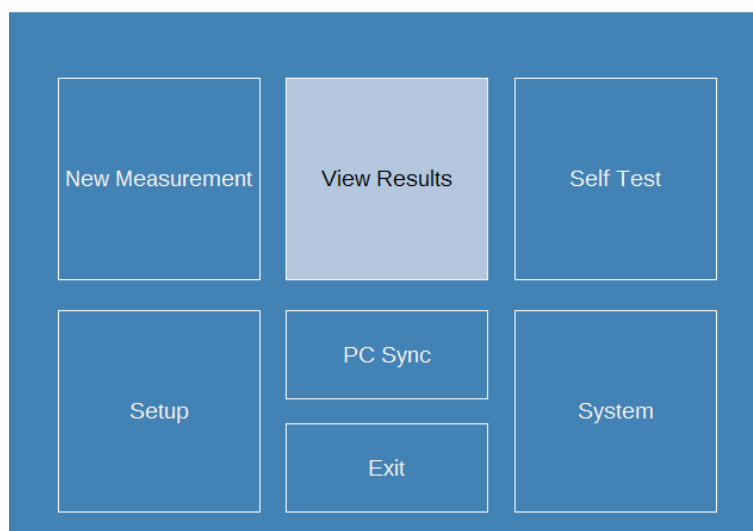


Figure 7-37: Main Menu

The Select Filter screens displays as shown in Figure 7-38. This provides several ways to search for measurement results. The default filter (in red) is **Show all**.

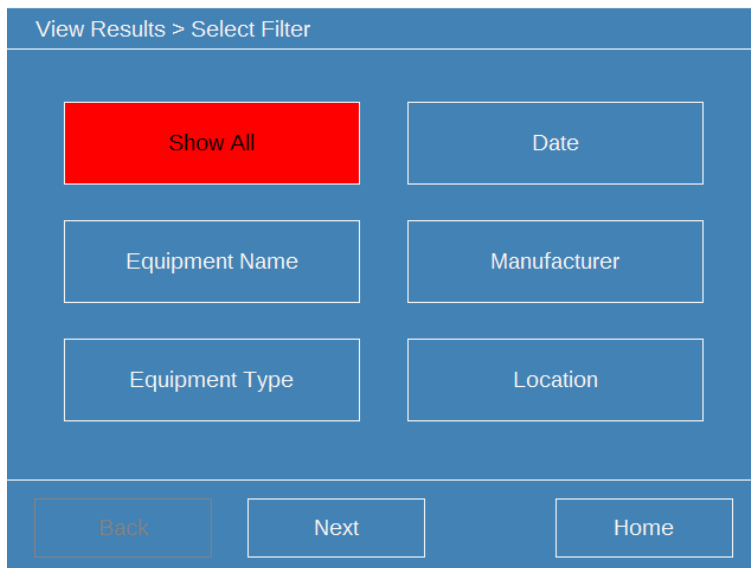


Figure 7-38: View Results > Select Filter

However, a search can be conducted using any of the following attributes:

- **Show All:** retrieves all records without filtering.
- **Date:** retrieves records between a range of dates.
- **Equipment Name:** retrieves records for a specific piece of equipment.
- **Manufacturer:** retrieves records for a specific manufacturer.
- **Equipment Type:** retrieves records for a specific category of equipment e.g. Transformer, Tap Changer or Circuit Breaker.
- **Location:** retrieves records for a specific location.

Press the appropriate button to conduct the relevant search. For example, to conduct a search based on the location category, press **Location**.

All the location records in the database are then listed on the Location screen as shown in Figure 7-39.

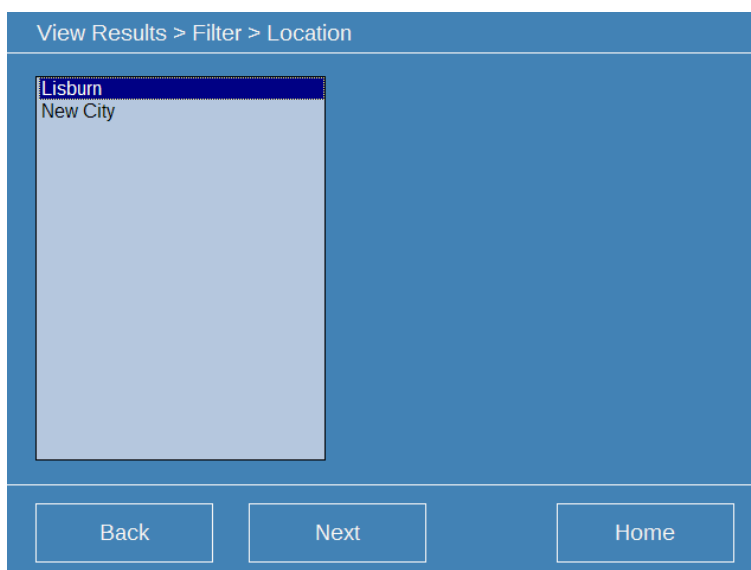


Figure 7-39: View Results > Filter > Location

Select the required location and press **Next**.

The Records screen displays a list of measurement records pertaining to this location as shown in Figure 7-40. Any records with errors are highlighted in yellow.

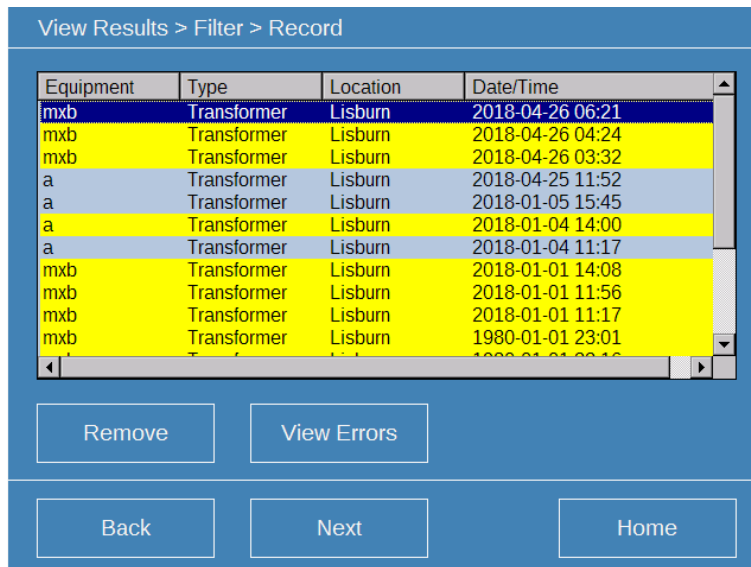


Figure 7-40: View Results > Filter > Location – Records

To see the available options, select the relevant record and press **Next**.

Note: To discard a record, select the record and press **Remove**. This will permanently delete the measurement record from the internal database.

Note: To view the errors associated with a record, select the record and press **View Errors** (see Section 7.6).

The Record Options screen displays with the following options as shown in Figure 7-41.

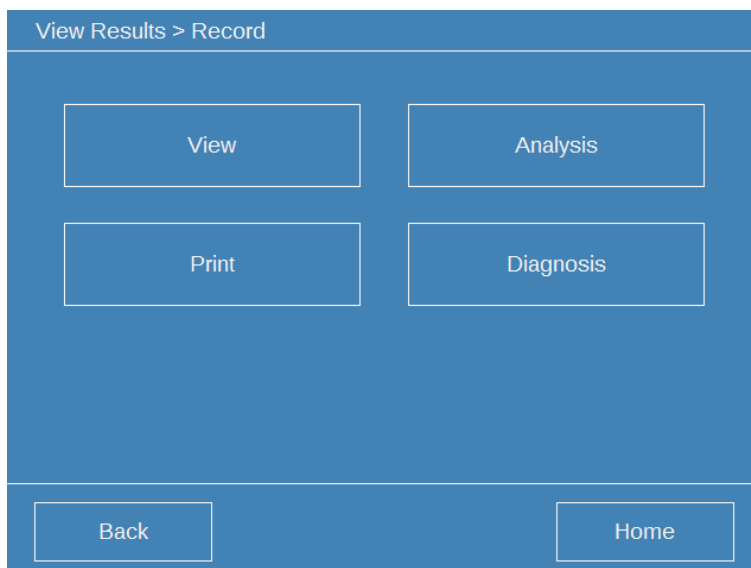


Figure 7-41: View Results > Filter > Record – options

Press **View** to see the measurement results for the selected record.

The Results screen displays as shown in Figure 7-42.

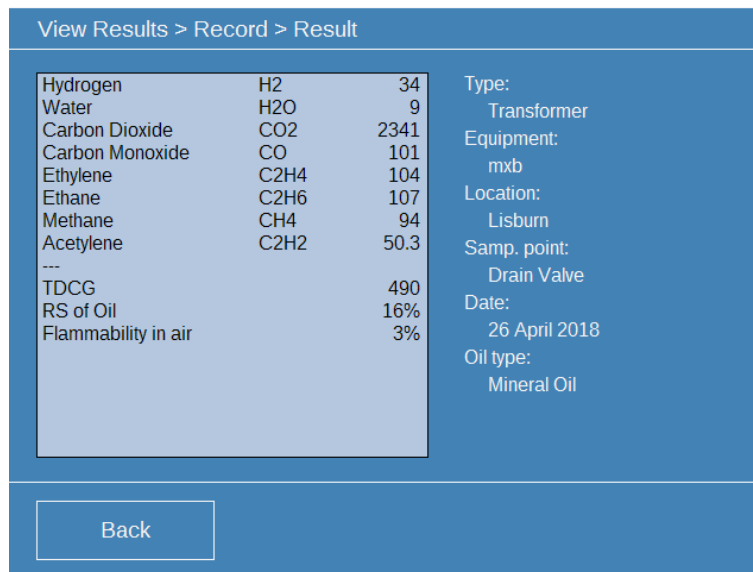


Figure 7-42: View Results > Filter > Records > View - results

The gas concentration measurements display on the left with the site equipment details on the right. Press **Back** to return to the Record Options screen as shown in Figure 7-43.

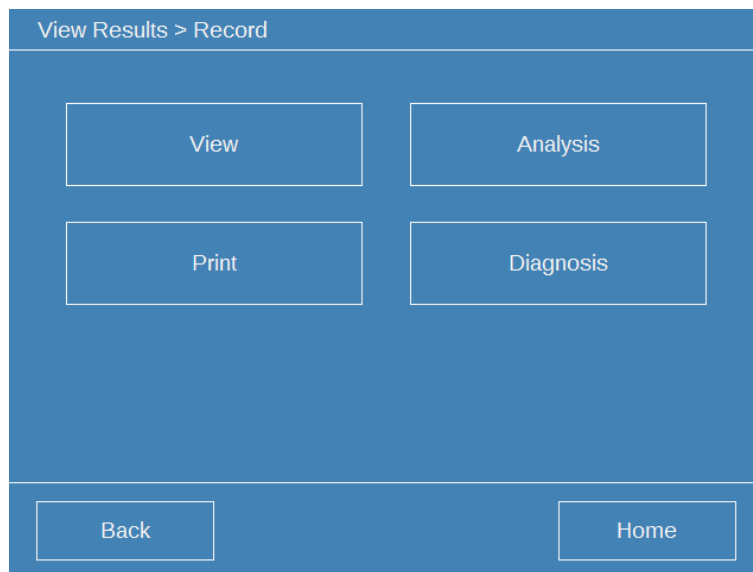


Figure 7-43: View Results > Filter > Record - options

Options exist to print the results, and perform analysis and diagnostics on the results. These options are discussed in Section 7.5.

All other searches are conducted in a similar manner to that described above for a location-based search, except for the 'Date' search, where the operator is required to set 'Start' and 'End' dates for the query as shown in Figure 7-44.

The screenshot shows a blue-themed interface titled "Date of sample". It contains two rows of input fields. The first row is labeled "Select search start date" and shows "Monday, March 05, 2018" next to a text box containing "2018-03-05". The second row is labeled "Select search end date" and shows "Monday, March 05, 2018" next to a text box containing "2018-03-05". At the bottom of the screen, there are two buttons: "Back" and "Next".

Figure 7-44: Date of Sample

Press the 'Start Date' or 'End Date' fields and use the onscreen numeric keypad to set the date as shown in Figure 7-45.

The screenshot shows the same "Date of sample" screen as Figure 7-44, but with a "Set date (yyyy-mm-dd)" keypad overlay. The keypad has three columns for "Year", "Month", and "Day". The "Year" field contains "2018", the "Month" field contains "3", and the "Day" field contains "5". Below these fields is a numeric keypad with buttons for digits 1-9, 0, a left arrow, a right arrow, a period, and a dash. At the bottom of the keypad are "OK" and "Cancel" buttons. The "Back" and "Next" buttons from the previous screen are visible at the bottom of the overlay.

Figure 7-45: Date of Sample > Set Date - keypad

Dates are entered on both the Start Date and End Date screens in the same manner. Press the relevant date part (Year, Month or Day) and use the numeric keypad to enter a valid date (Year > 2000), Month (1-12) and Day (1-31).

7.5 Analysis & Diagnosis

The product includes several software-based analytical and diagnostic tools for examining DGA results. These tools, as described below, are based on widely recognized standards and algorithms in conjunction with various operator-configured caution and warning alarm limits.

Note: The resulting analysis does not necessarily represent the opinion of GE.

The Record Options screen presents several options for examining DGA results as shown in Figure 7-46.

Note: Analytical and diagnostic options are available only for transformer oil samples.

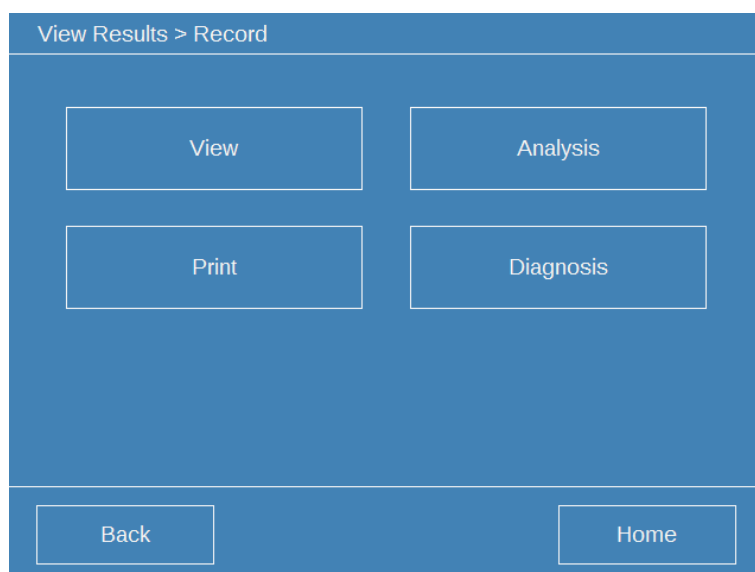


Figure 7-46: View Results > Filter > Record – options

- Press **View** to again see the raw gas measurement figures as shown previously in Section 7.3.4 and as discussed in Section 7.4.
- Press **Print** to activate the product's built-in thermal printer and obtain a printout of the Measurement Results and Diagnostic Analysis Results, for example, as shown in Figure 7-47.
- Press **Analysis** to see the raw gas measurement figures with the gas limits applied as described below in Section 7.5.1.
- Press **Diagnosis** to use the product's DGA diagnostic software tools to process the measurement results as described below in section 7.5.2.
- Press **Home** to return to the Main Menu screen as shown in Figure 7-37.

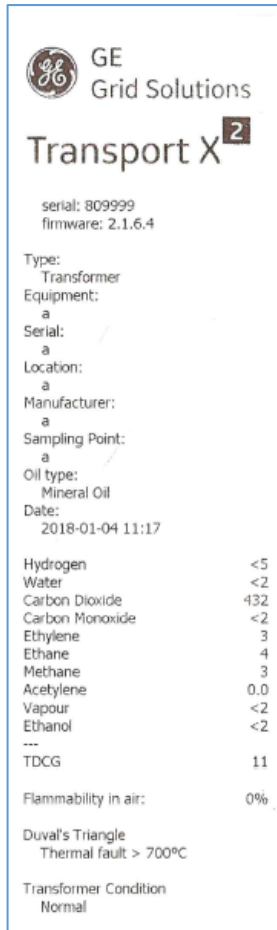


Figure 7-47: Transport X² printout

If the operator has chosen **'Tap Changer'**, **'Circuit Breaker'** or **'Other'** as the Equipment Type (see Figure 7-6), then the analytical and diagnostic options do not apply and the operator is presented with the message as shown in Figure 7-48.

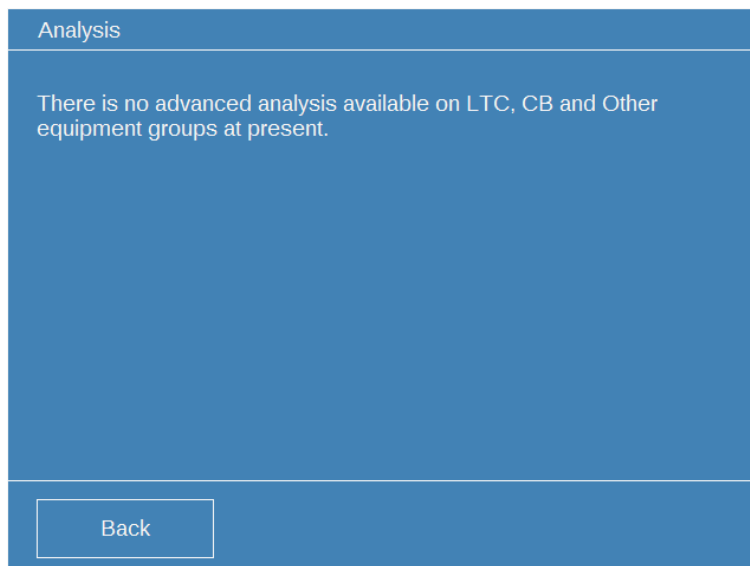


Figure 7-48: Error – Analytical and diagnostic options not applicable

7.5.1 Analysis using Gas Limits

The Analysis screen displays the results overlaid with Caution and Warning highlights as shown in Figure 7-49. This is derived from applying the gas threshold or limit values as configured in Section 7.3.1 (see Figure 7-17).

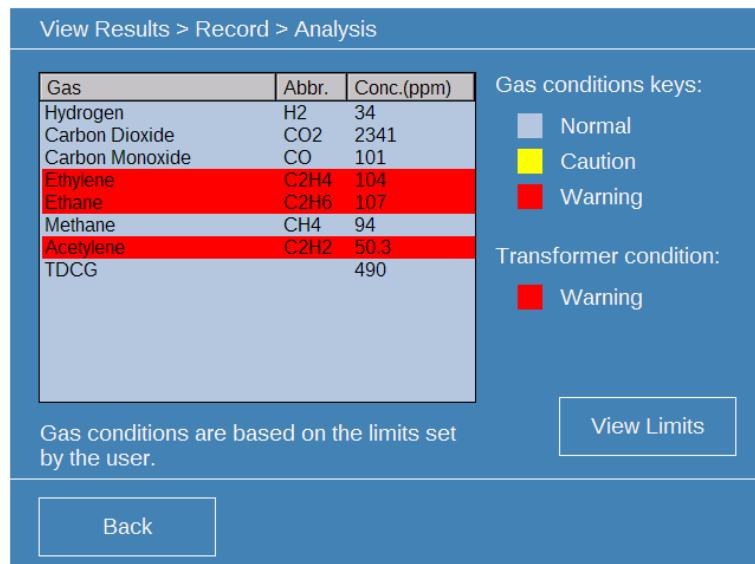


Figure 7-49: Analysis – Caution and Warning levels

This analysis compares measured dissolved gas concentration levels with the preconfigured Caution and Warning levels for each gas.

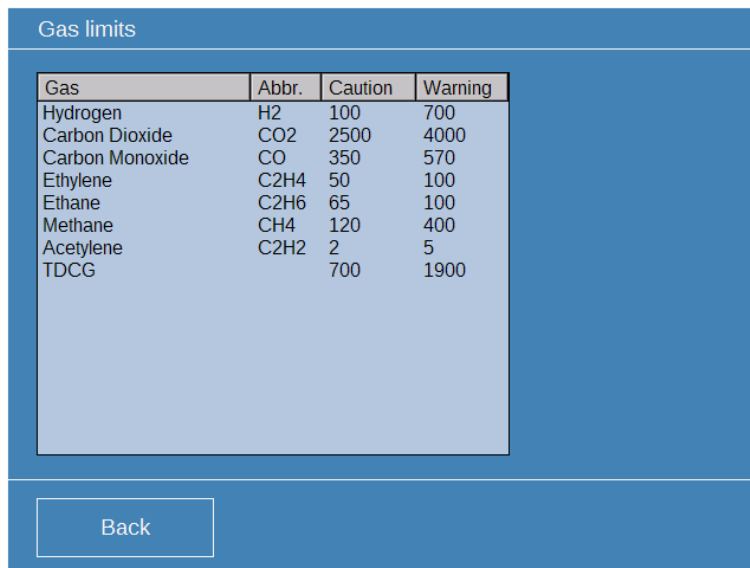
Note: Default gas concentration threshold levels are configurable as described below.

If the measured concentration value for any gas is above one of the threshold levels for that gas, the gas entry is color-coded accordingly as follows: yellow (if above the Caution level) or red (if above the Warning level). An overall Transformer Condition assessment is also provided (color-coded Normal, Caution or Warning) based on the gas alarm levels.

Press **View Limits** to view the current gas concentration threshold limits.

(If applicable, see Section 7.5.2 for Diagnostic options.)

The Gas Limits screen displays as shown in Figure 7-50.



Gas	Abbr.	Caution	Warning
Hydrogen	H2	100	700
Carbon Dioxide	CO2	2500	4000
Carbon Monoxide	CO	350	570
Ethylene	C2H4	50	100
Ethane	C2H6	65	100
Methane	CH4	120	400
Acetylene	C2H2	2	5
TDCG		700	1900

Back

Figure 7-50: Analysis > Gas Limits

To change the Caution and/or Warning threshold levels, press **Back** and navigate back to the Main Menu screen as shown in Figure 7-51.

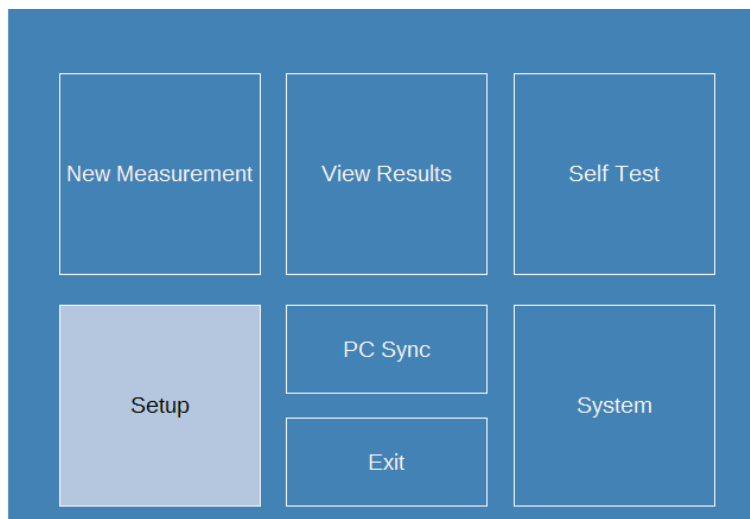


Figure 7-51: Main Menu

From the Main Menu, press **Setup > Gas Limits**. The Gas Limits screen displays as shown in Figure 7-52.

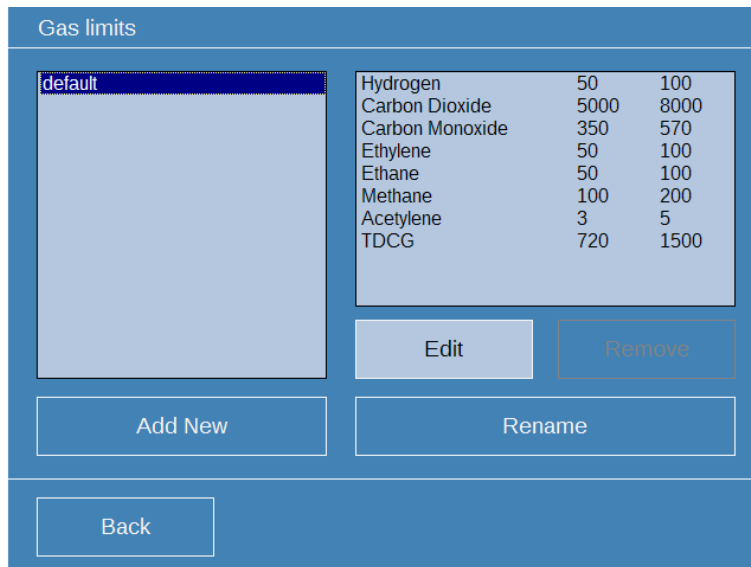


Figure 7-52: Setup > Gas Limits - names

To modify any of the gas limit values, select the 'gas limit name' and press **Edit**.

The display changes to the Gas Limits values screen as shown in Figure 7-53. Here the Caution and Warning PPM limits are set for each gas.

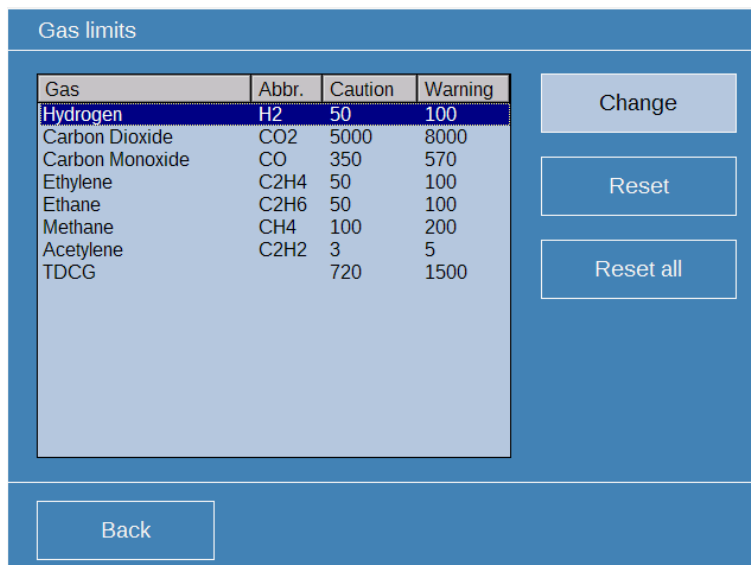


Figure 7-53: Setup > Gas Limits > Edit - values

It is possible to modify the PPM gas limits for any individual gas, reset individual gas limits to the default setting or reset all gas limits to the default setting. For example, to change the limits for a gas, select the gas e.g. Hydrogen and press **Change**.

The Set Gas Limits onscreen keypad displays as shown in Figure 7-54.

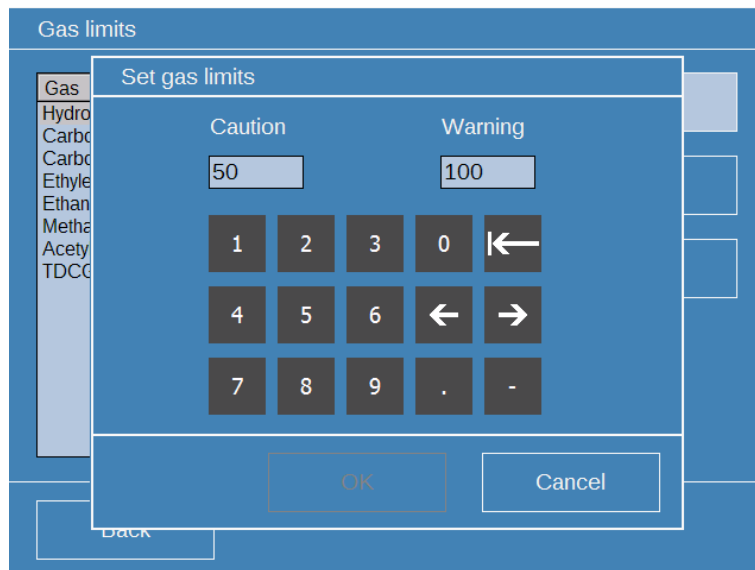


Figure 7-54: Setup > Gas Limits > Edit - values - keypad

Use the numeric keypad to modify the 'Caution' or 'Warning' values for the gas as appropriate, for example, as shown in Figure 7-55 and press **OK**.



Figure 7-55: Setup > Gas Limits > Edit - values - keypad - new

The Gas Limits values screen displays with the revised Caution and Warning limits as shown in Figure 7-56.

Gas	Abbr.	Caution	Warning
Hydrogen	H2	49	99
Carbon Dioxide	CO2	5000	8000
Carbon Monoxide	CO	350	570
Ethylene	C2H4	50	100
Ethane	C2H6	50	100
Methane	CH4	100	200
Acetylene	C2H2	3	5
TDCG		720	1500

Buttons: Change, Reset, Reset all, Back

Figure 7-56: Gas Limits – values - new

Press **Back** > **Back** > **Home** to return to the Main Menu as shown in Figure 7-57.

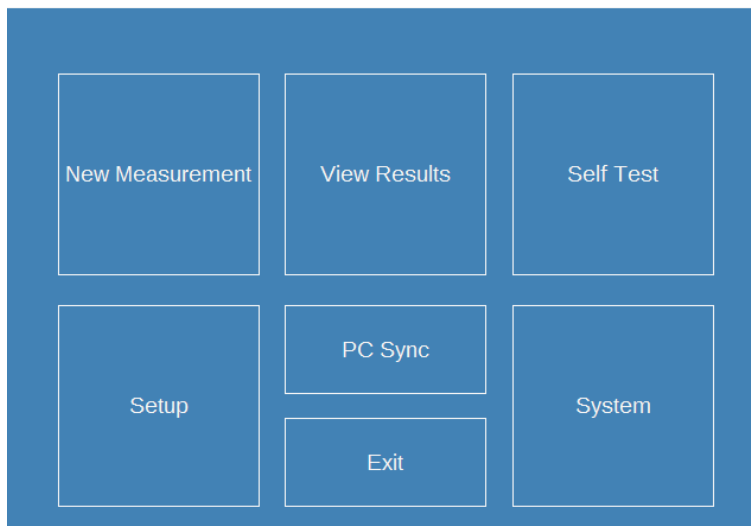


Figure 7-57: Main Menu

7.5.2 Diagnosis using Industry Standard Diagnostics

The Diagnostic Tools screen displays as shown in Figure 7-58.

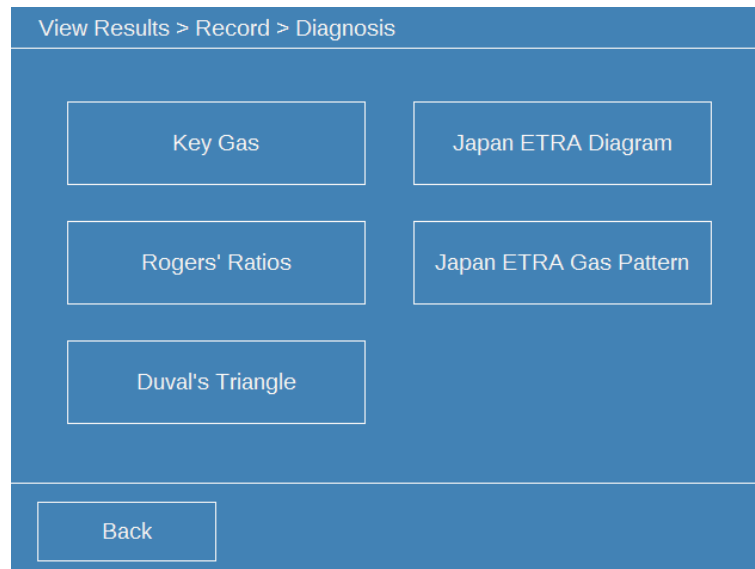


Figure 7-58: Diagnostic Tools

Five diagnostic tools are available:

- [Key Gas](#)
- [Rogers' Ratios](#)
- [Duval's Triangle](#)
- [Japan ETRA Diagram](#)
- [Japan ETRA Gas Pattern](#)

All these diagnostic tools are based on empirical data derived from the study of transformer degradation and failures. They are not designed to definitively detect transformer faults, but rather intended to provide advance warning of *potential* failures and *aid* in the diagnosis of transformer faults.

If the gas levels are low and the transformer does not appear to have a fault, these algorithms should not be applied as they could give misleading results. Alternatively, perform DGA analysis using the operator-configurable Caution and Warning thresholds already described in Section 7.5.1.

Choose the relevant diagnostic tool, e.g. **Key Gas**. A relevant information notice displays. If the gas levels are very low, an additional message displays at the bottom in red as shown in Figure 7-59.

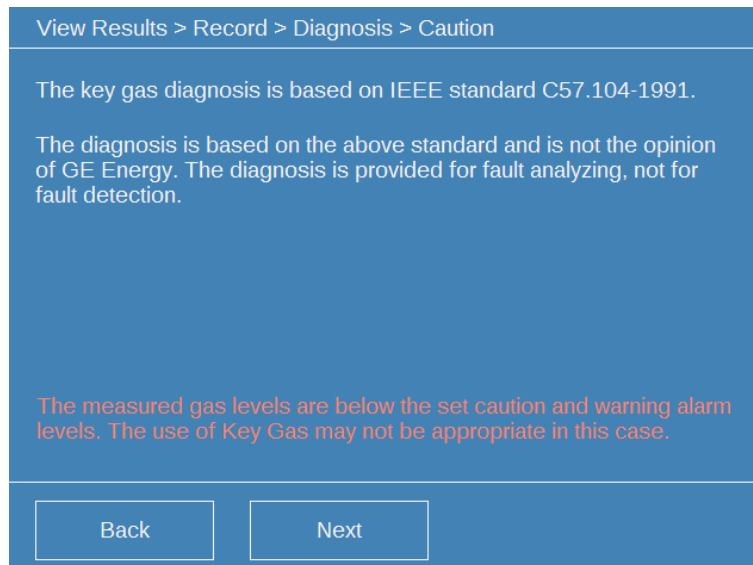


Figure 7-59: View Results > Record > Diagnosis > Key Gas – Caution notice

Note: All issues concerning diagnostic tools are explored in the standards and references cited on the caution or information notice.

7.5.2.1 Key Gas – IEEE C57.104 1991

The Key Gas information notice displays as shown in Figure 7-60. Press **Next** to continue.

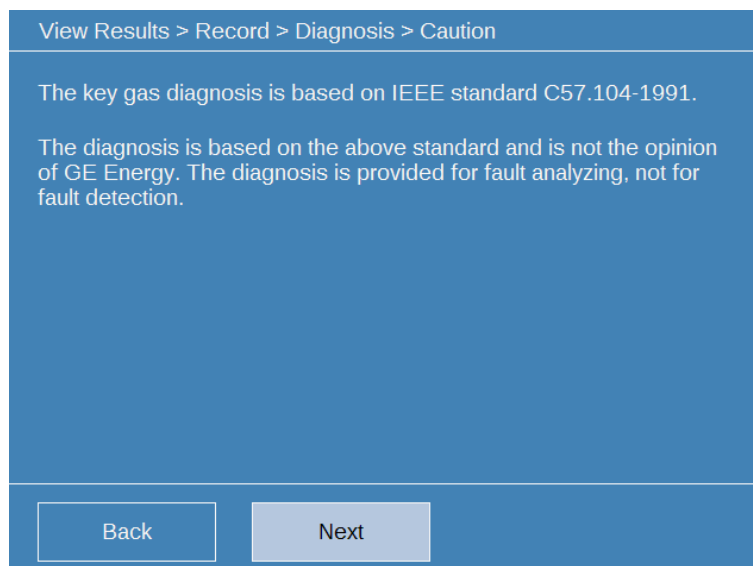


Figure 7-60: View Results > Record > Diagnosis > Key Gas – notice

The Key Gas tool allows a visual comparison of the current Transport X² DGA results against the results of four 'typical' diagnoses as shown in Figure 7-61. Use the onscreen arrow buttons to scroll through and determine which, if any, of the typical diagnoses (color-coded green), most closely resembles the current Transport X² DGA results (color-coded amber).

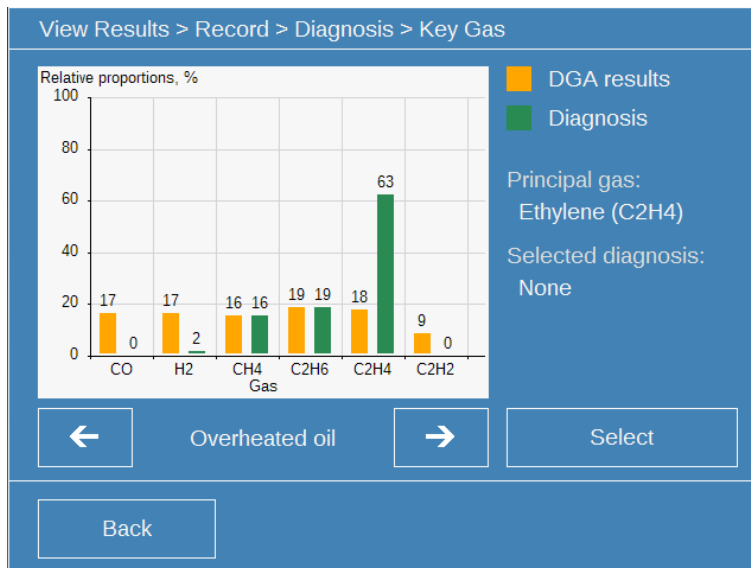


Figure 7-61: View Results > Record > Diagnosis > Key Gas

Press **Select** to choose the diagnosis that most closely resembles (if any) that of the Transport X² DGA results.

Note: Do not make a diagnosis selection if there is no applicable comparison.

7.5.2.2 Rogers' Ratios – IEEE C57.104 1991

The Diagnosis Information notice displays as shown in Figure 7-62. Press **Next** to continue.

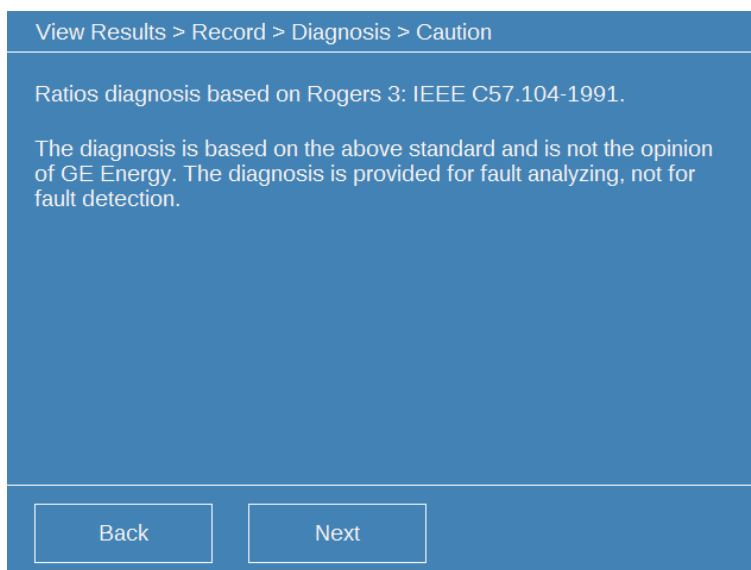


Figure 7-62: View Results > Record > Diagnosis > Rogers' Ratios - notice

The Rogers' Ratios tool uses established ratios between various dissolved gases to determine the type of fault as shown in Figure 7-63. However, if the gas concentration levels are low, the Rogers' Ratios screen displays a warning to notify that gas levels may be too low for this algorithm to produce a reliable result. The fault code and diagnosis may still be displayed, but caution should be used when applying this result. Press **Back** to return to the Diagnostic Tools screen.

Rogers' ratios	
Ratio	Value
CH4 / H2 (R1)	NaN
C2H2 / C2H4 (R2)	NaN
C2H4 / C2H6 (R5)	NaN
C2H6 / CH4	NaN
CO2 / CO	NaN
Rogers 3 Case:	None
Diagnosis:	No diagnosis available
Rogers 4 Code:	2 1 2 2
Diagnosis:	No diagnosis available

Some gas concentrations are too low to provide a reliable diagnosis

Back

Figure 7-63 View Results > Record > Diagnosis > Rogers' Ratios - notice

7.5.2.3 Duval's Triangle - TechCon 2004 - Michel Duval

The Diagnosis Information notice displays as shown in Figure 7-64. Press **Next** to continue.

View Results > Record > Diagnosis > Caution

Duval's triangle based on dissolved gas analysis a powerful maintenance tool for transformers by Michel Duval (TechCon® 2004 NA)

The diagnosis is based on the above standard and is not the opinion of GE Energy. The diagnosis is provided for fault analyzing, not for fault detection.

Back Next

Figure 7-64: View Results > Record > Diagnosis > Duval's Triangle - notice

The Duval's Triangle tool uses a triangle to plot the intersecting point of certain gas concentration values as shown in Figure 7-65. The location of the point within the triangle indicates the possible type of fault on the transformer with the diagnosis noted to the bottom right of the screen. Press **Back** to return to the Diagnostic Tools screen.

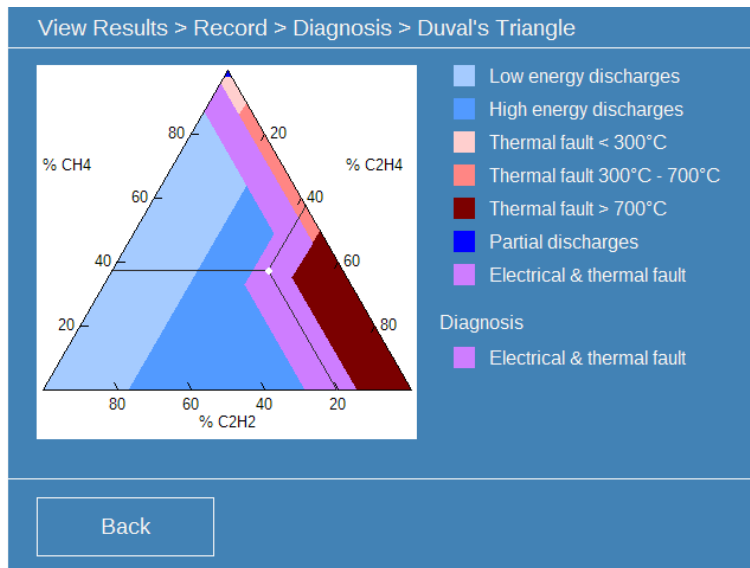


Figure 7-65: View Results > Record > Diagnosis > Duval's Triangle

7.5.2.4 Japan ETRA – Volume 54, No. 5

The Japanese Electric Technology Research Association (ETRA) has reviewed many DGA diagnoses in Japan and elsewhere, and has reached certain conclusions regarding the detection of faults in transformers. From these studies, Japan ETRA have established a series of patterns associated with specific types of failure. These patterns depict the relative concentration levels of certain dissolved gases (H₂, CH₄, C₂H₆, C₂H₂ and C₂H₄) in the oil of failing transformers at the time of internal faults. Based on this research, Japan ETRA have also produced two diagnostic charts or diagrams based on the ratios of concentrations of certain dissolved gases that have been correlated with types of transformer failure:

- [Diagnostic Diagrams](#)
- [Gas Pattern Analysis](#)

These Japan ETRA forms of failure diagnosis have been incorporated into the Transport X² diagnostic software tools and are described below.

a) Japan ETRA Diagrams

The Diagnosis Information notice displays as shown in Figure 7-66. Press **Next** to continue.

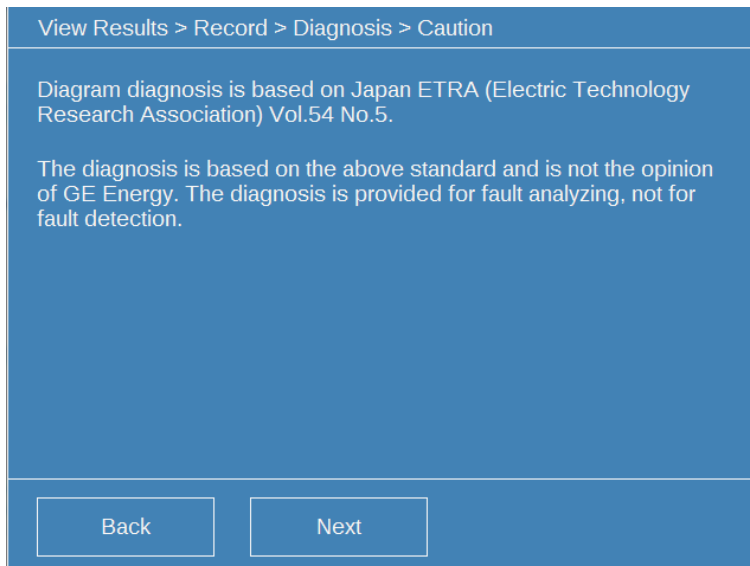


Figure 7-66: View Results > Record > Diagnosis > Japan ETRA - notice

Japan ETRA illustrates the ratio of gases present at the time of internal faults in a transformer as shown in Figure 7-67. The white spot is the result derived from the most recent set of dissolved gas concentration measurements made by the Transport X² for the gas ratios used in this diagram. In this example, the diagram suggests a diagnosis of discharges.

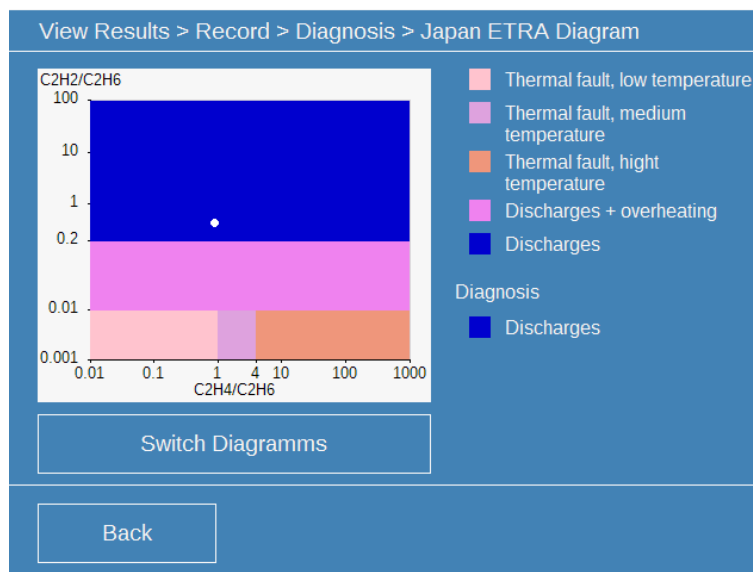


Figure 7-67: View Results > Record > Diagnosis > Japan ETRA Diagnostic Diagram A

Press **Switch Diagrams** to toggle between the diagnostic diagrams. The second diagnostic diagram displays as shown in Figure 7-68.

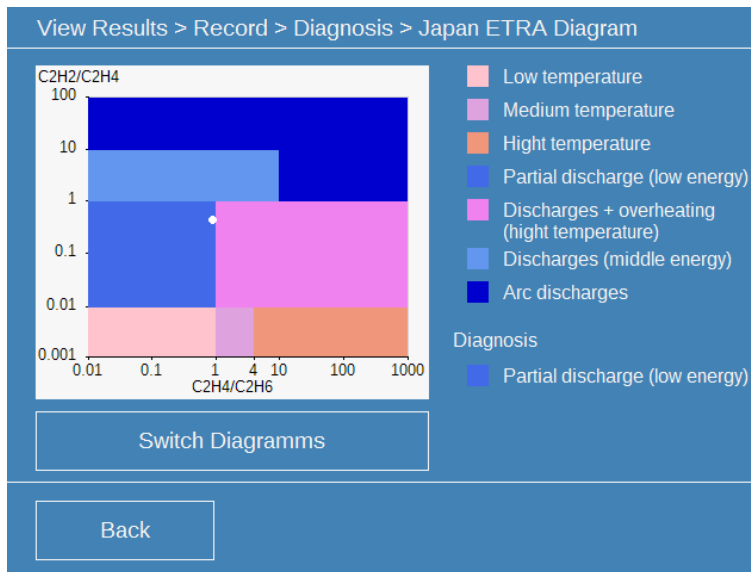


Figure 7-68: View Results > Record > Diagnosis > Japan ETRA Diagnostic Diagram B

Again, the white spot is the result derived from the most recent set of dissolved gas concentration measurements made by the Transport X² using the gas ratios of the second diagnostic diagram. In this example, the diagram suggests a diagnosis of partial discharge (low energy).

Press **Back** to return to the Diagnostic Tools screen.

b) Gas Pattern Analysis

The Diagnosis Information notice displays as shown in Figure 7-69. Press **Next** to continue.

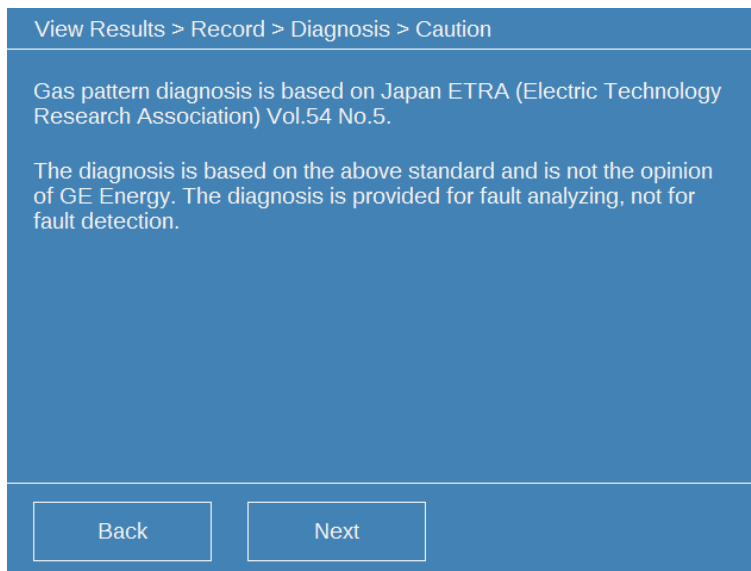


Figure 7-69: View Results > Record > Diagnosis > Japan ETRA Gas Pattern - notice

The Japan ETRA gas pattern is as shown in Figure 7-70. The left plot (color-coded amber) is the dissolved gas pattern produced by the Transport X² based on the most recent measurement sample, whereas the right plot (color-coded green) represents a series of pre-determined gas patterns derived from the Japan ETRA analysis of transformer failures.

Note: The Transport X² measurement sample pattern is produced in an identical manner to the pre-determined failure patterns using a process of normalization based on the highest concentration level of the dissolved gas detected in the oil of a failing transformer.

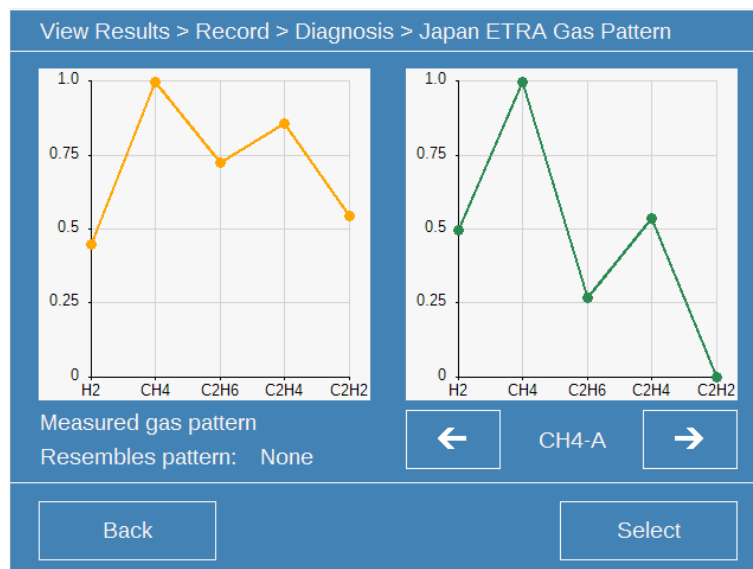


Figure 7-70: Japan ETRA Gas Pattern – measurement pattern V pre-determined failure patterns

The product makes available several such ETRA gas patterns, each pattern representing a different type of failure. Use the onscreen arrow buttons to scroll through the series of pre-determined failure patterns on the right (green) and compare each in turn against the DGA results gas pattern of the Transport X² on the left (amber).

Press **Select** to choose the pattern on the right that most closely resembles (if any) that of the DGA results gas pattern of the Transport X² on the left.

Note: Do not make a gas pattern selection if there is no applicable comparison.

Press **Back** to return to the Diagnostic Tools screen.

7.5.3 Concluding the Analysis & Diagnosis

To conclude the analysis and diagnostics, press **Back** to exit the Diagnostic tools as shown in Figure 7-71.

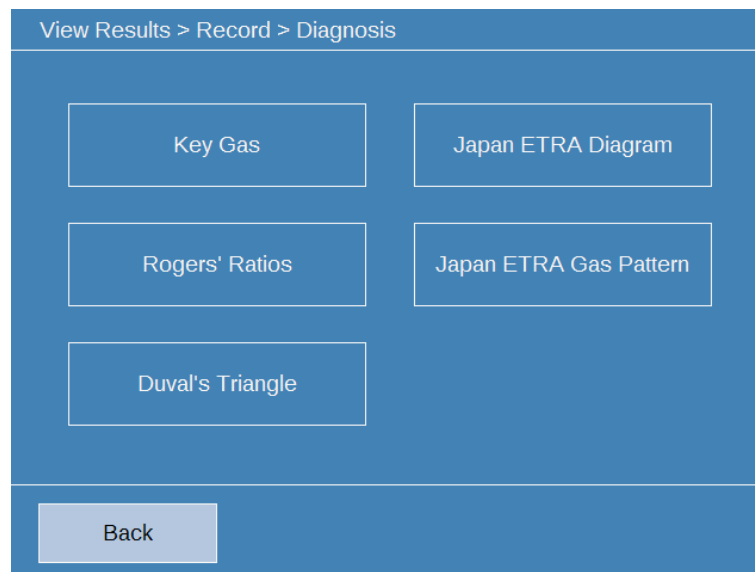


Figure 7-71: Diagnostic Tools

This returns the operator to the Record Options screen as shown in Figure 7-72 (discussed previously in Section 7.4 and 7.5), where it is also possible to print the Measurement results and Diagnostic Analysis results.

Note: Diagnostic analysis data is automatically saved.

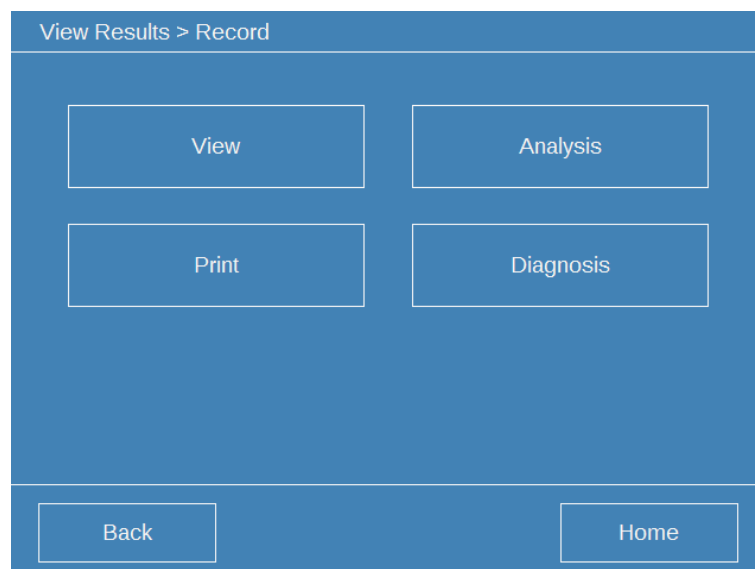


Figure 7-72: View Results >Filter > Record - options

Press **Home** to return to the Main Menu screen as shown in Figure 7-73. Shutdown the product, if required, as outlined in Section 7.1.

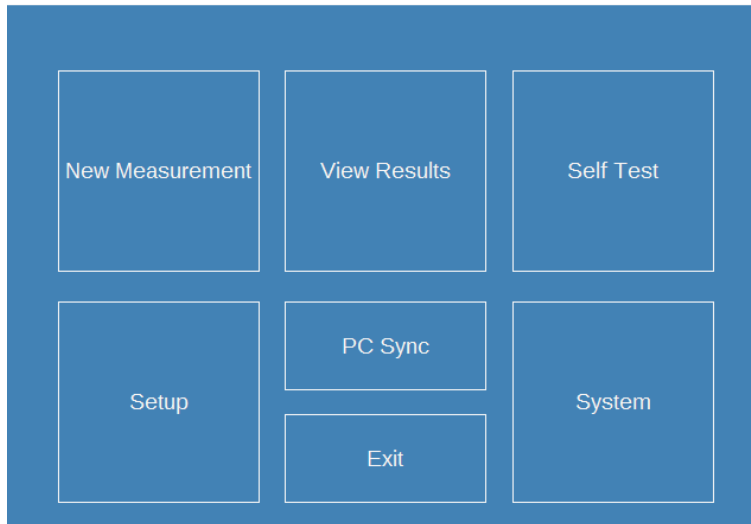


Figure 7-73: Main Menu

7.6 View Errors

The product includes several self-diagnostic functions for monitoring the internal operation of the system and checking the validity of oil samples. If an anomaly is detected, this will be reported to the operator at the end of the sample measurement process.

In addition, when viewing the results, the database records screen as shown in Figure 7-74 highlights in yellow any records where one or more errors have been raised (see Section 7.4 for further information about viewing records and results). **Note:** The currently selected record is highlighted in blue.

If the operator selects a result that is subject to an error, the **View Errors** button becomes active as shown in Figure 7-74.

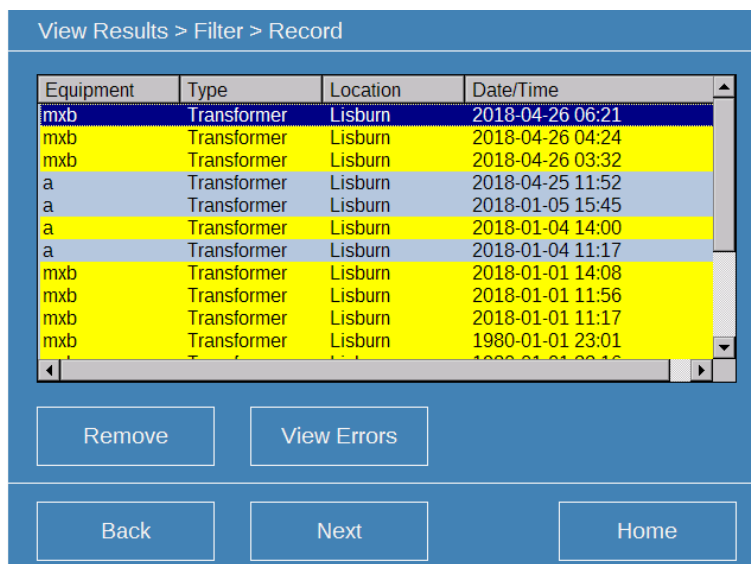


Figure 7-74: View Results > Records – highlighted with errors

To view the errors associated with a measurement record, select the record and press **View Errors**.

The View Errors screen displays as shown in Figure 7-75. Any error codes and corresponding descriptions for each fault detected by the product are listed.

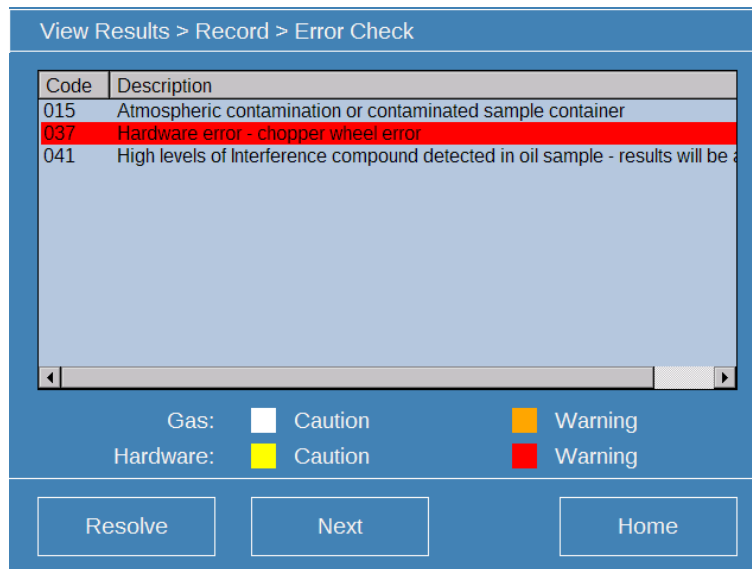


Figure 7-75: View Results > Records > View Errors

Errors are classified as either hardware (instrument) or gas (environmental). Hardware errors relate to an issue with the product, whereas gas errors relate to an issue with the sample being measured or the local environment. Errors are color-coded as follows:

- White: denotes a gas-related caution: an issue has arisen with the sample, but the results are still valid, albeit they may have a larger than normal margin for error. This can arise when high target gas levels are detected in the ambient air. To resolve, the operator could potentially move the product to another location for further sample testing or increase the purge time of future tests.
- Orange: denotes a gas-related warning: the product has detected a serious problem with the sample, rendering the results as unreliable. Typically, this means there has likely been some interference or contamination with obtaining, injecting or storing the sample in some way, for example, not following the sampling procedure correctly or using a cleaning solvent.
- Red: denotes a hardware warning: a serious product error requiring the operator to contact GE Technical Support immediately.
- Yellow: denotes a hardware caution: a minor error requiring the operator to take certain action to resolve, for example, changing the in-line filters. If the error persists, contact GE Technical Support.

For records with errors, a function exists to obtain help on resolving the errors or preventing a reoccurrence of the error.

Press **Resolve** for a list of the recommended courses of action for each error code.

The Error Check Resolve screen displays as shown in Figure 7-76 with specific courses of actions to help in the resolution of the error.

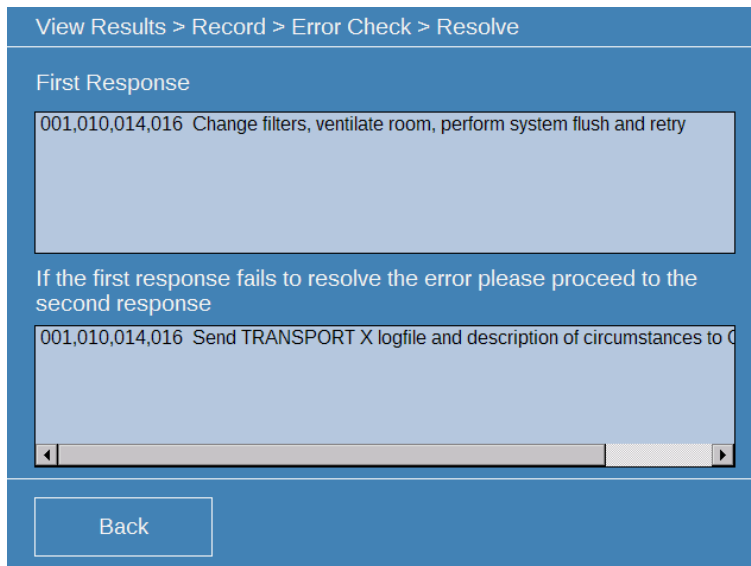


Figure 7-76: View Results > Records > View Errors > Resolve

Follow the instructions in the First response section and, subsequently if this fails to resolve the error, proceed to the Second response.

Users can also refer to 'Section 13 Troubleshooting' for resolution suggestions. If the error cannot be resolved, contact GE Technical Support.

Note: If a user chooses to continue a measurement without resolving any raised errors, results may be affected. A message to this effect displays as shown in Figure 7-77.

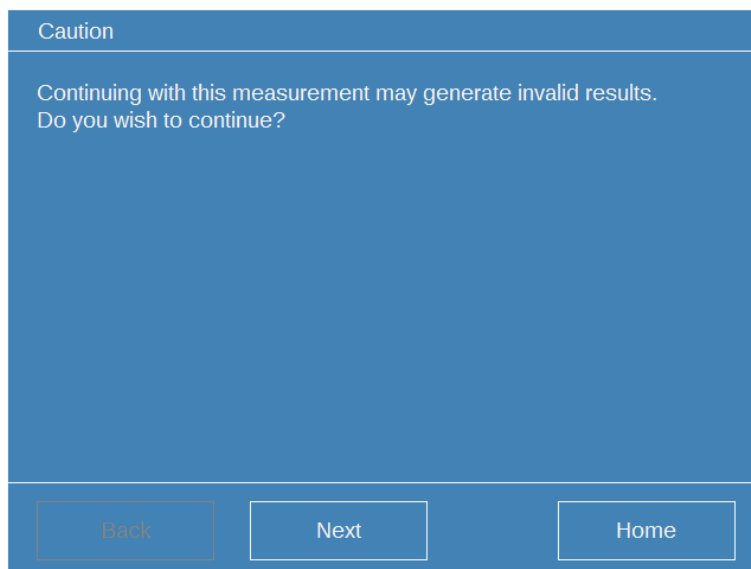


Figure 7-77: Proceeding with Unresolved Errors – Caution message

7.7 Setup

From the Main Menu screen as shown in Figure 7-78, press **Setup** to examine the available settings.

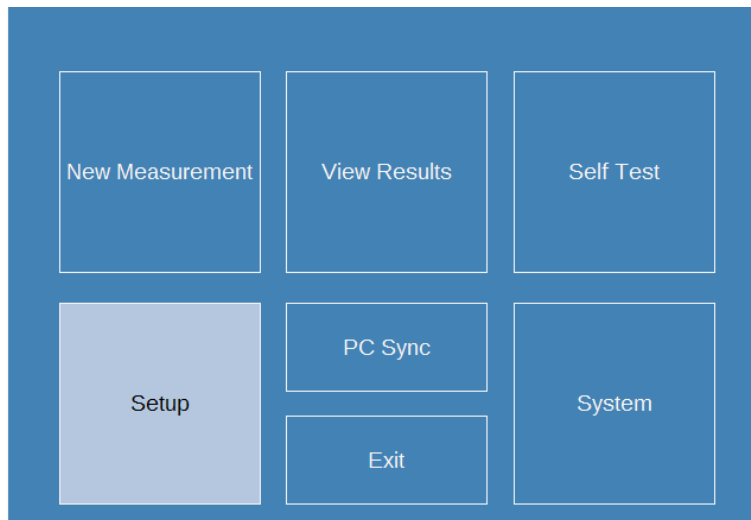


Figure 7-78: Main Menu

The Setup screen displays as shown in Figure 7-79.

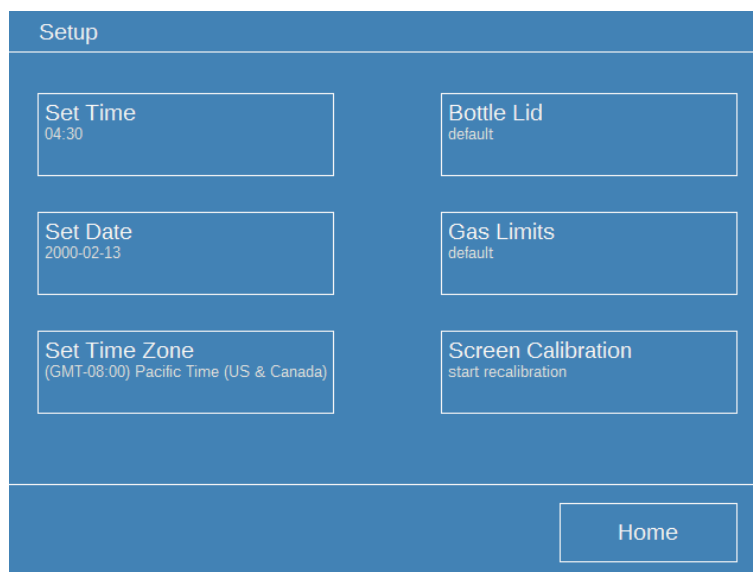


Figure 7-79: Setup > Settings

This screen allows the operator to control the following aspects of the product as described below:

- Set Time
- Set Date
- Set Time Zone
- Bottle Lid
- Gas Limits
- Screen Calibration

Press **Home** to return to the Main Menu screen.

7.7.1 Time

Press **Set Time** to set the time on the product using the 24-hour clock. Press the relevant time field and use the numeric keypad to enter the hour (0-23) and minutes (0-59) as shown in Figure 7-80.

Note: The database is pre-populated with several Time Zones relative to GMT. Select the closest time zone.

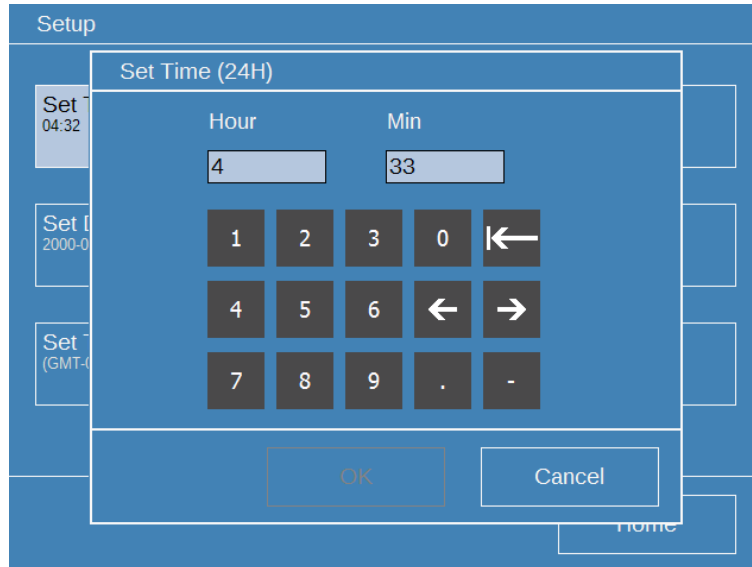


Figure 7-80: Settings > Set Time – keypad

7.7.2 Date

Press **Set Date** to set the date on the product in the format yyyy-mm-dd. Press the relevant date field and use the numeric keypad to enter the Year (>2000), Month (1-12) and Day (1-31) as shown in Figure 7-81.

Note: The database is pre-populated with several Time Zones relative to GMT. Select the closest time zone.

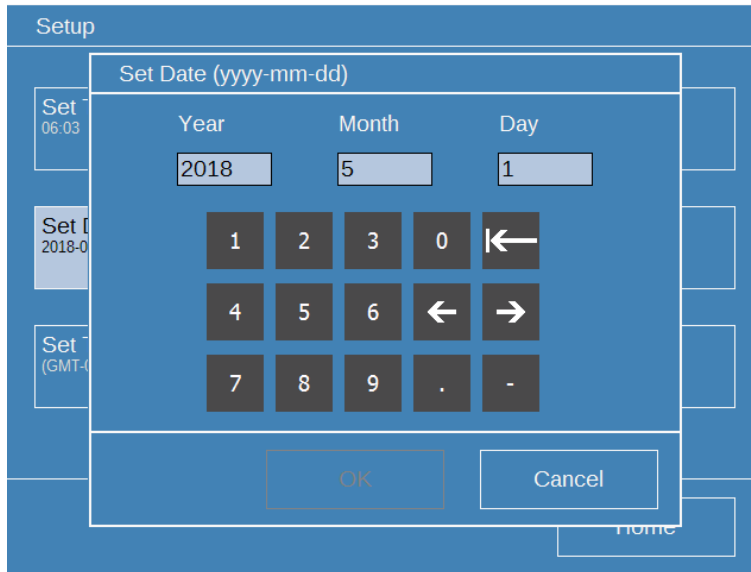


Figure 7-81: Settings > Set Date – keypad

7.7.3 Time Zone

Press **Set Time Zone** to set the time zone for the product. The database is pre-populated with several Time Zones relative to GMT. Select the closest time zone and press **Back** to action the change as shown in Figure 7-82.

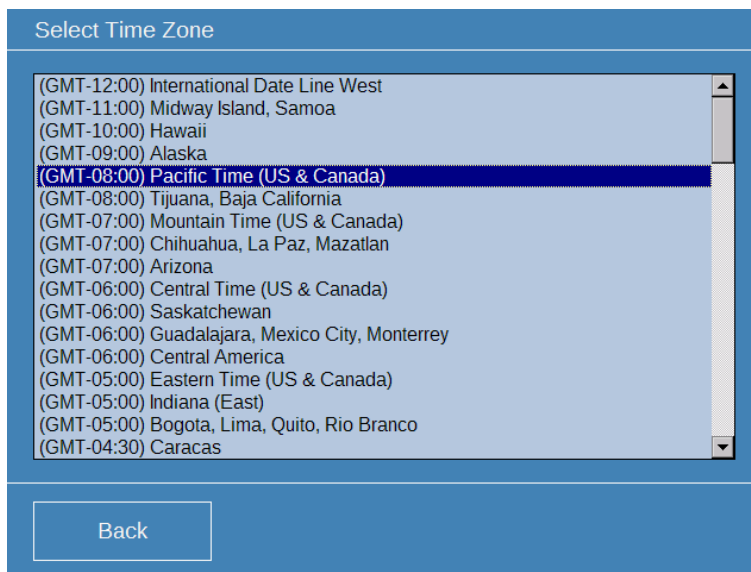


Figure 7-82: Select Time Zone

7.7.4 Bottle Lid

Refer to Section 12 for details on exchanging the bottle lid assembly.

7.7.5 Gas Limits

Refer to Section 7.5.1 for details on viewing and modifying the gas limits.

7.7.6 Screen Calibration

Use this option to adjust the sensitivity of the touchscreen as shown in Figure 7-83. **Note: It is not recommended to change the default settings for the touchscreen.**

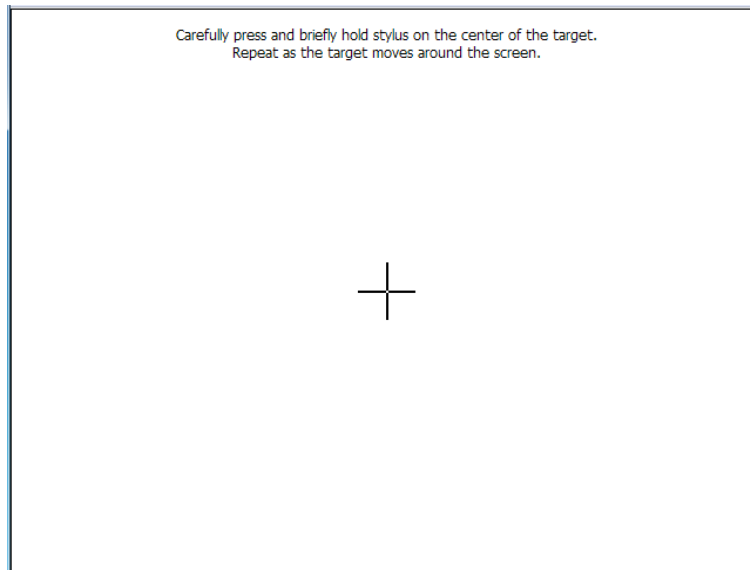


Figure 7-83: Screen calibration - start

Follow the onscreen instructions as shown in Figure 7-84 until the new calibration settings have been measured.



Figure 7-84: Screen calibration - end

7.8 System

7.8.1 Language

Use this option to select the desired language from the available list.

7.8.2 Configuration

System-level settings for configuring various aspect of the Transport X², such as calibration and PGA settings. This area is password protected and reserved for GE service staff.

7.8.3 About

Provides product details, such as serial numbers and firmware versions. To upgrade the firmware, refer to Section 11.3.

7.9 Integrity Tests

From the Main Menu screen as shown in Figure 7-85, press **Self Test** to see the available integrity tests. Use this option to perform essential system checks and maintenance on the product.

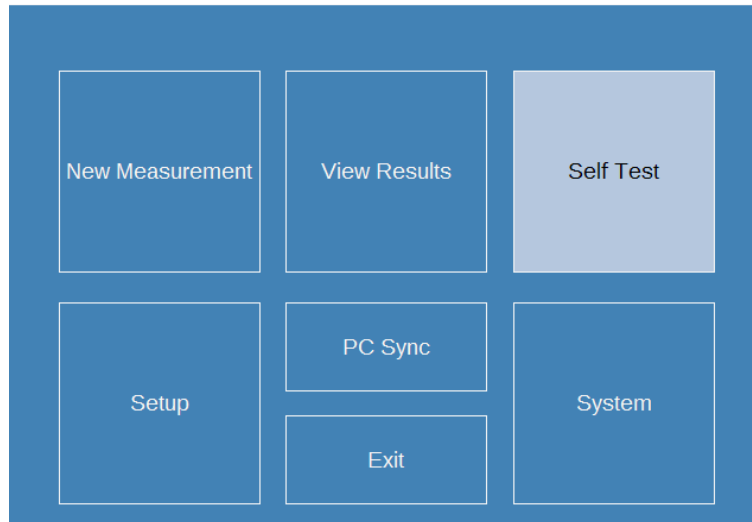


Figure 7-85: Main Menu

The Self Test screen displays as shown in Figure 7-86.

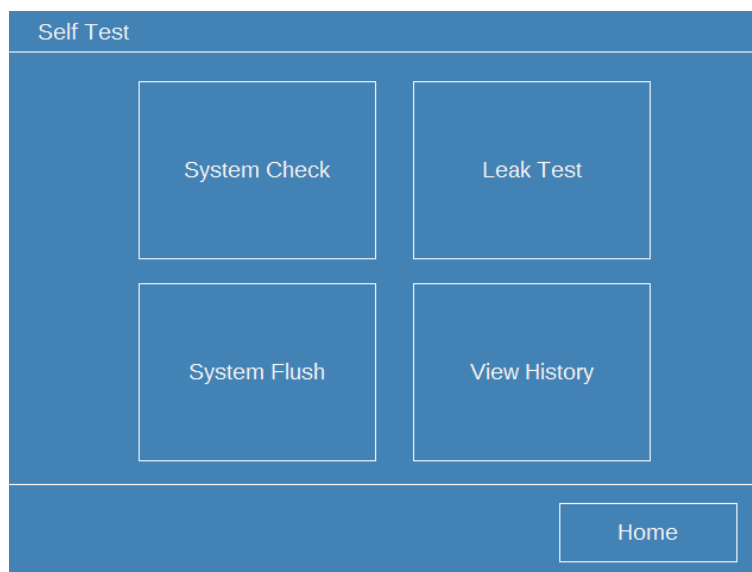


Figure 7-86: Integrity Tests

The product provides several options for system checking and maintenance of the product as outlined below.

- [System Check](#)
- [System Flush](#)
- [Leak Test](#)
- [View History](#)

7.9.1 System Check

Refer to Section 10 for details on the System Check.

7.9.2 System Flush

The System Flush is a means of cleansing the product of any residue contamination as mentioned in Section 5.6. Press **System Flush** to flush ambient air through the product for 20 minutes to help clear any potential contamination from packing material or the testing of previous samples.

The System Flush instructions screen displays as shown in Figure 7-87.

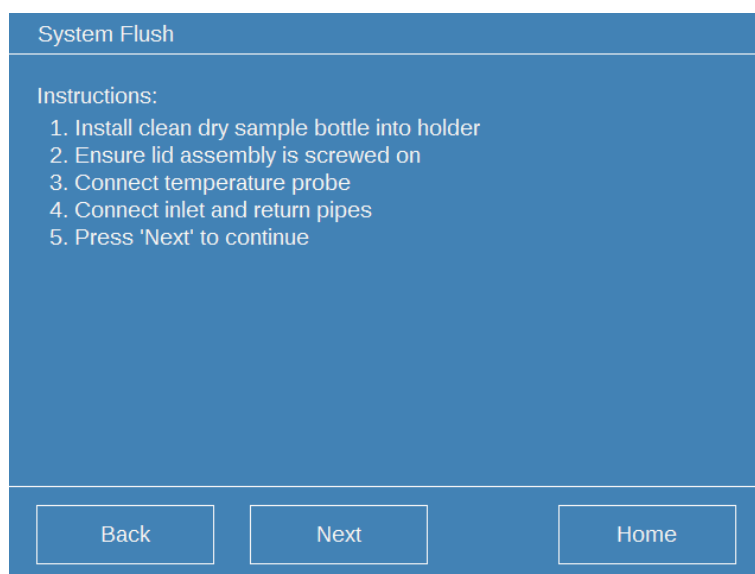


Figure 7-87: System Flush - instructions

Connect a clean, dry sample bottle to the product and follow the onscreen instructions. Press **Next** to initiate the flushing process.

The Flushing Progress screen displays as shown in Figure 7-88.

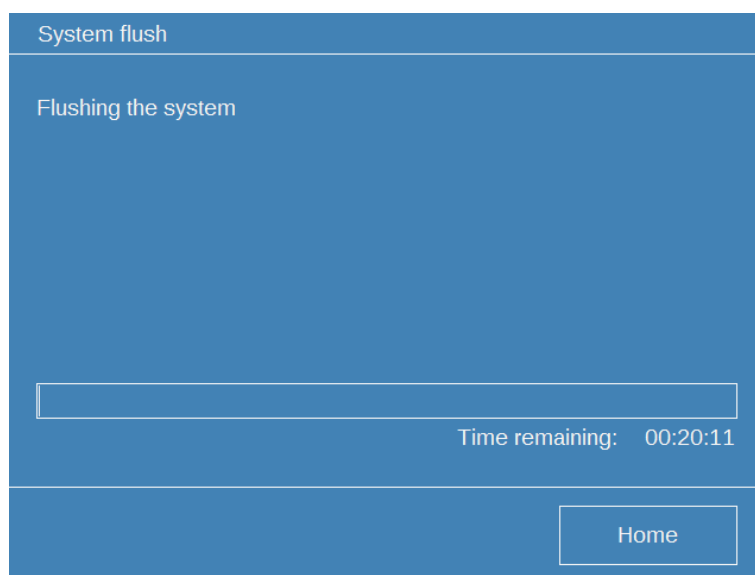


Figure 7-88: System Flush - countdown

A progress bar indicates progress. The flushing process takes approximately 20 minutes to complete.

Note: Press **Home** to terminate the flushing process at any time and return to the Integrity Tests menu.

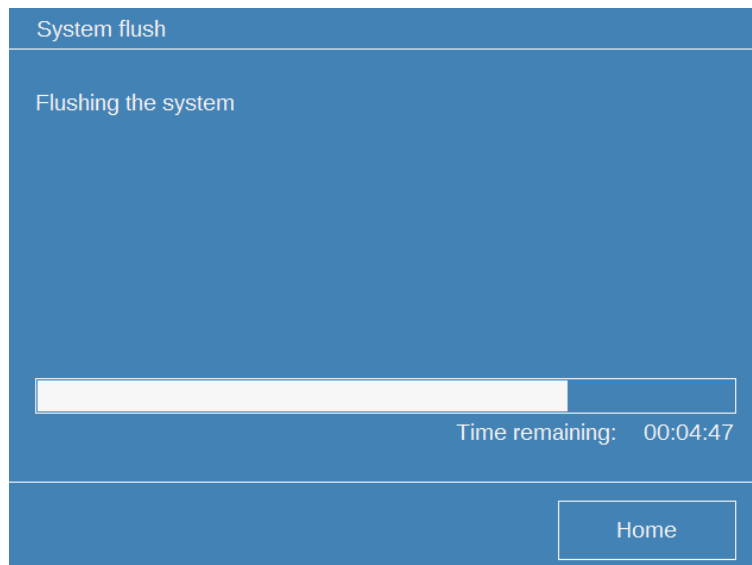


Figure 7-89: System Flush - progress

When the system flush completes, the System Flush completed screen displays as shown in Figure 7-90.

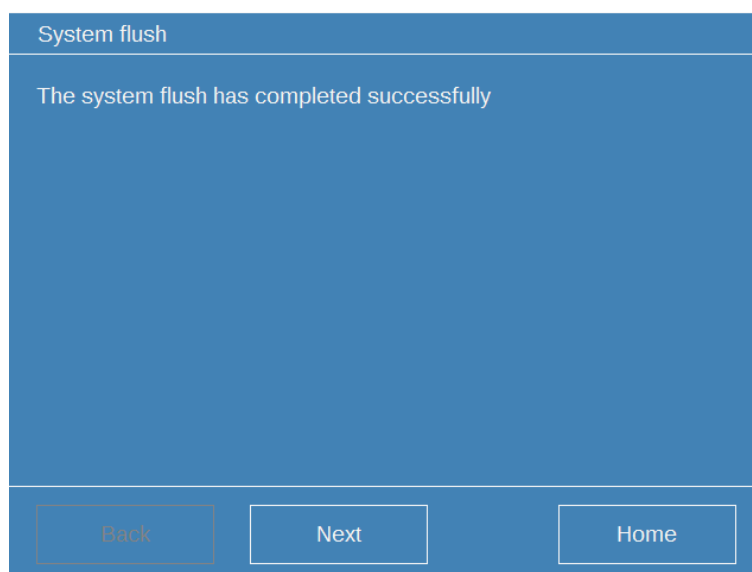


Figure 7-90: System Flush - complete

Press **Next** to return to the Integrity Tests menu.

7.9.3 Leak (Pressure) Test

The Leak Test is a means of checking the ability of the product to maintain pressure in the working gas system. Press **Leak Test** to initiate a system pressure test.

The Pressure Test instructions screen displays as shown in Figure 7-91.

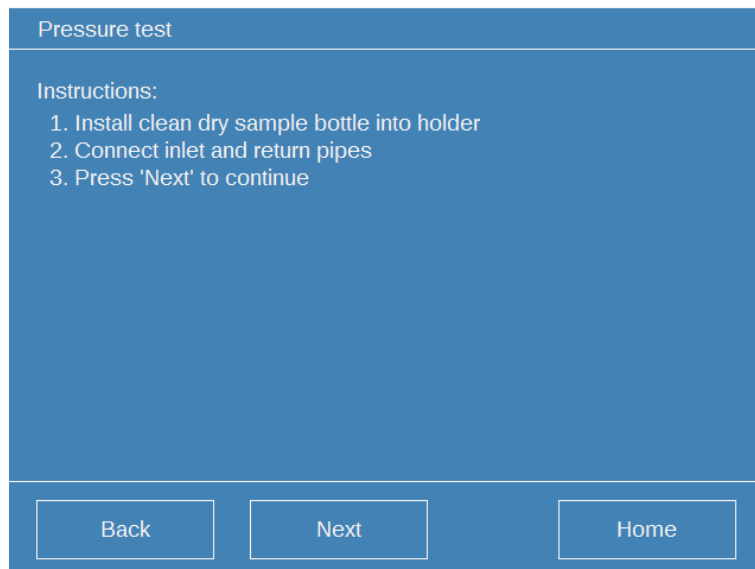


Figure 7-91: Pressure Test - instructions

Connect a clean, dry sample bottle to the product and follow the onscreen instructions. Press **Next** to initiate the pressure test.

The Pressure Test progress screen displays with a countdown from approximately 2 minutes as shown in Figure 7-92.

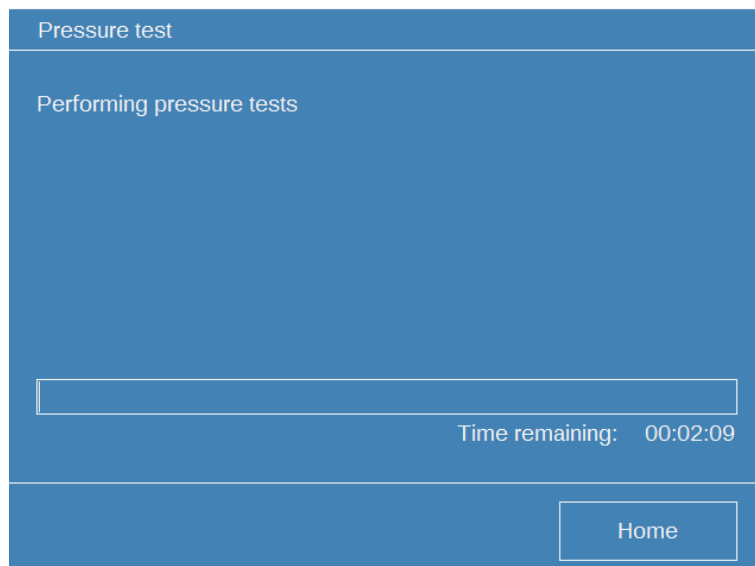


Figure 7-92: Pressure Test - progress

If pressure can be maintained, the Pressure Test Passed screen displays as shown in Figure 7-93.

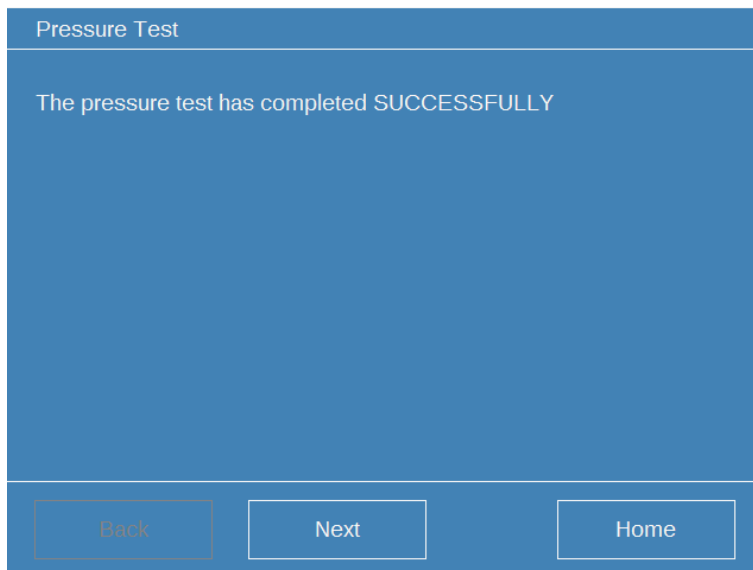


Figure 7-93: Pressure Test - passed

If pressure cannot be maintained (i.e. a leak is detected) in the working gas system, the Pressure Test Failed screen displays as shown in Figure 7-94.

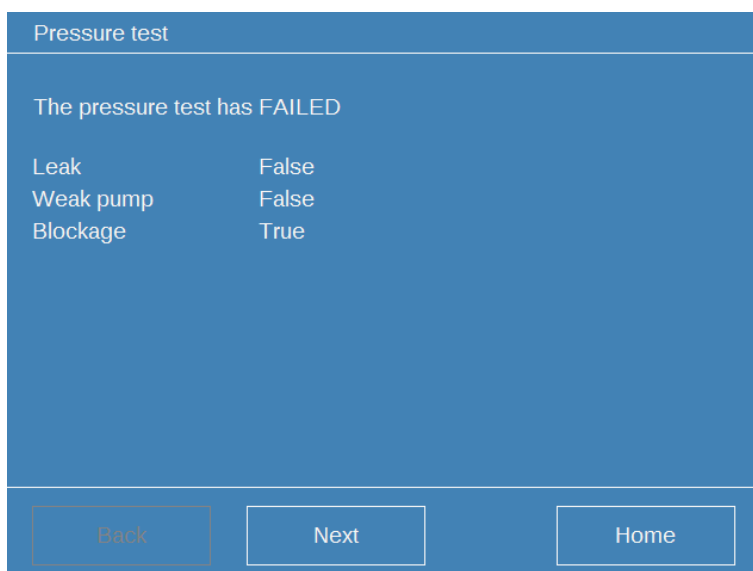


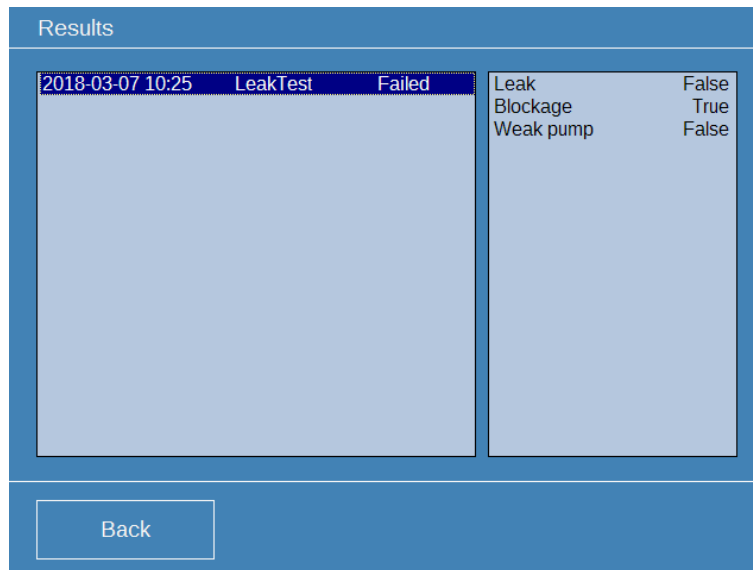
Figure 7-94: Pressure Test - failed

Check the seal around the bottle lid and filters. Ensure they are a tight fit and replace if necessary. Repeat the Pressure Test. Contact GE if the problem persists.

Press **Next** for more information on the failures or **Home** to return to the Integrity Tests menu.

7.9.4 View History

To review all the previous tests conducted on the product (System Checks and Leak Tests), press **View History**. The Tests Results screen displays as shown in Figure 7-95.



The screenshot shows a 'Results' screen with a blue header. The main content is divided into two panels. The left panel is a table with one row of test data. The right panel shows the detailed results for the selected test. At the bottom, there is a 'Back' button.

2018-03-07 10:25	LeakTest	Failed

Leak	False
Blockage	True
Weak pump	False

Back

Figure 7-95: Tests Results

The left panel lists all tests and the right panel displays the results of the selected test.

Press **Back** to return to the Integrity Tests menu.

8 CLEANING

It is essential to thoroughly clean the apparatus after every sample analysis to prevent cross contamination from one sample to the next. A small amount of residual oil left in the sample container or injection pipework may have an impact on the results of the next sample. The cleaning techniques outlined in Section 8.1 and Section 8.2 are designed to ensure that the product is always ready for the next test.

Note: The same oil sample cannot be re-tested since most of the gas will have already escaped during analysis.

After the product has completed a sample analysis, the oil sample should be disposed of as outlined in Section 2.4 and the bottle and lid assembly cleaned. The sample bottle, the oil injection port on the bottle lid with female quick-connect valve, the syringe with its three-way valve and male quick-connect valve should all be thoroughly cleaned. Wipe all surfaces with a clean dry absorbent cloth or tissue.



Do not use any solvents to clean any part of the product or its accessories as this may cause the unit to flag ambient contamination warnings and could also compromise the sample and thus the reported results.

Ensure that no oil residue remains in the oil injection port or the syringe's three-way valve. The valves on the syringe and the oil injection port on the bottle lid are cleaned by pumping ambient air from the syringe. Refer to the online operator videos for a demonstration of 'Oil injection port cleaning'.

Note: Use a cloth or waste container to catch any residue.

8.1 Bottle & Lid Assembly

Follow these steps to clean the sample bottle and lid assembly:

1. Unscrew the lid assembly from the sample bottle, holding the lid assembly upright to avoid any oil ingress into the tubes.
2. Clean the underside of the lid assembly, pipework and adjoining tubes with a clean cloth or tissue.
3. Dispose of the degassed oil sample responsibly (see Section 2.4) and clean the inside of the bottle thoroughly with a clean cloth or tissue. (Alternatively, replace the oil sample bottle with another clean and dry bottle).

8.2 Oil Injection Port, Syringe & Valves

Expel any residue oil from the oil injection port and valves by pushing ambient air from a clean dry syringe. This process flushes any remaining residue of oil from the oil injection port on the bottle lid, as well as the three-way valve and male quick-connect valve that is fitted to the syringe.

Follow these steps to connect the syringe:

1. Ensure the male quick-release valve as shown in Figure 7-28 is connected to the syringe.
2. Connect the syringe to the oil injection port on the lid assembly using the male quick-connect valve on the syringe (see Figure 7-28) and join it to the female quick-connect valve on the lid assembly (see Figure 7-29).

Follow these steps to use the syringe as a pump to forcefully flush air through the valves to remove any remaining oil residue into the waste container or bottle:

3. Turn the three-way valve on the syringe to permit air to be drawn into the syringe through the side arm of the valve (i.e. reposition the stopcock so that it points down).
4. Pull the plunger back to draw air into the syringe.
5. Turn the three-way valve to close the side arm and open the in-line arm (i.e. reposition the stopcock at right-angles as shown in Figure 7-30).
6. Push the plunger forward to pump air through the syringe, valves and oil injection port.
7. Repeat steps 3 to 6 four or five times or as often as necessary to remove any trace of oil.

Remove the syringe when the flushing process is complete. Clean the inside of the bottle thoroughly with a cloth or tissue. It is also recommended to clean the syringe after each sample and before storage / reuse. Turn the stopcock up so that the plunger and barrel are airlocked to prevent the plunger from dropping out during transit.

If no other test is to be undertaken, disconnect the pipework from the top panel of the product, screw the lid assembly back onto the sample bottle, and place the sample bottle/lid assembly (including the connecting tubes with filters) back in the accessories case as shown in Figure 5-2.

9 BUCHHOLZ RELAYS

The product supports sampling and analysing gases from gas-collecting Buchholz relays. This section details the procedure for sampling gas and injecting it into the product for measurement.

The apparatus in the sampling kit (KIT00005) includes:

- A 5-ml gastight syringe with Luer lock termination and integrated valve
- A 3.17 mm (1/8 in.) ID section of gas impermeable plastic tube
- A three-way plastic stopcock with Luer terminations male-male-female.

9.1 Gas Sampling

Gas samples from relays should be taken from the equipment with minimum delay after gas accumulation has been signaled. Follow this procedure to sample the gas:

1. Connect the Buchholz sampling point to the stopcock (2) of the syringe using the supplied plastic tube as shown in Figure 9-1.
2. Allow any oil in the sampling tube to run to waste (6) as shown in Figure 9-1.

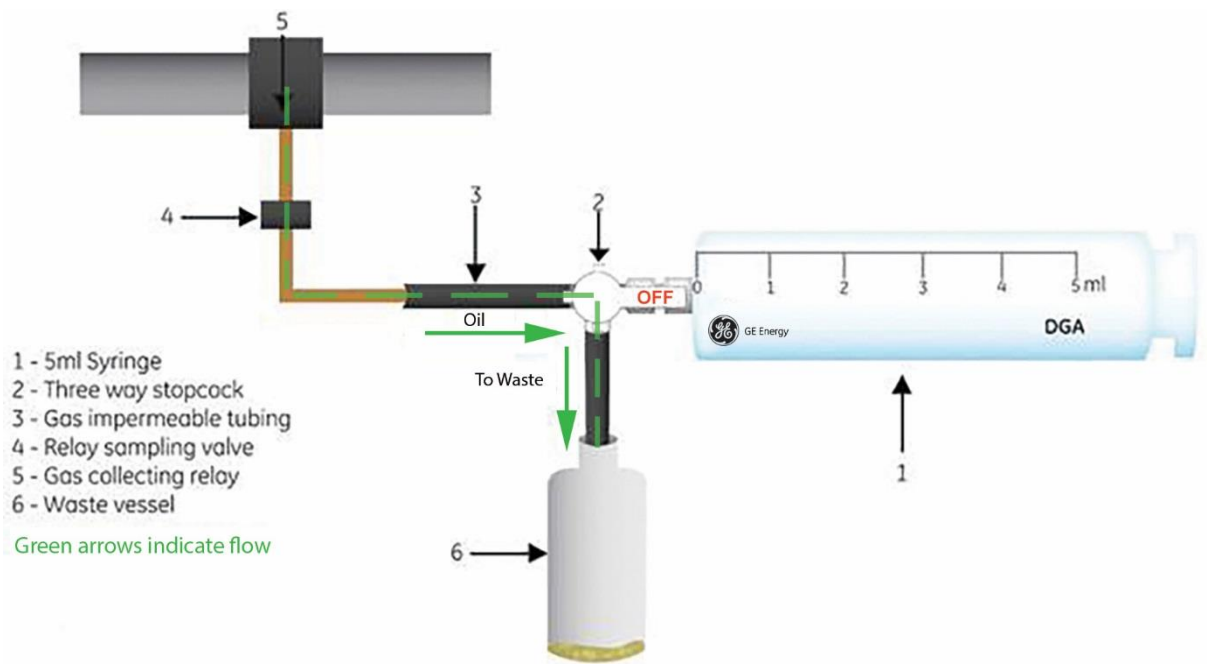


Figure 9-1: Oil flows to waste container

3. When gas starts to flow, adjust the three-way stopcock to allow the gas to fill the syringe by the hydrostatic pressure in the relay, as shown in Figure 9-2, taking care that the gas pressure does not eject the plunger completely.

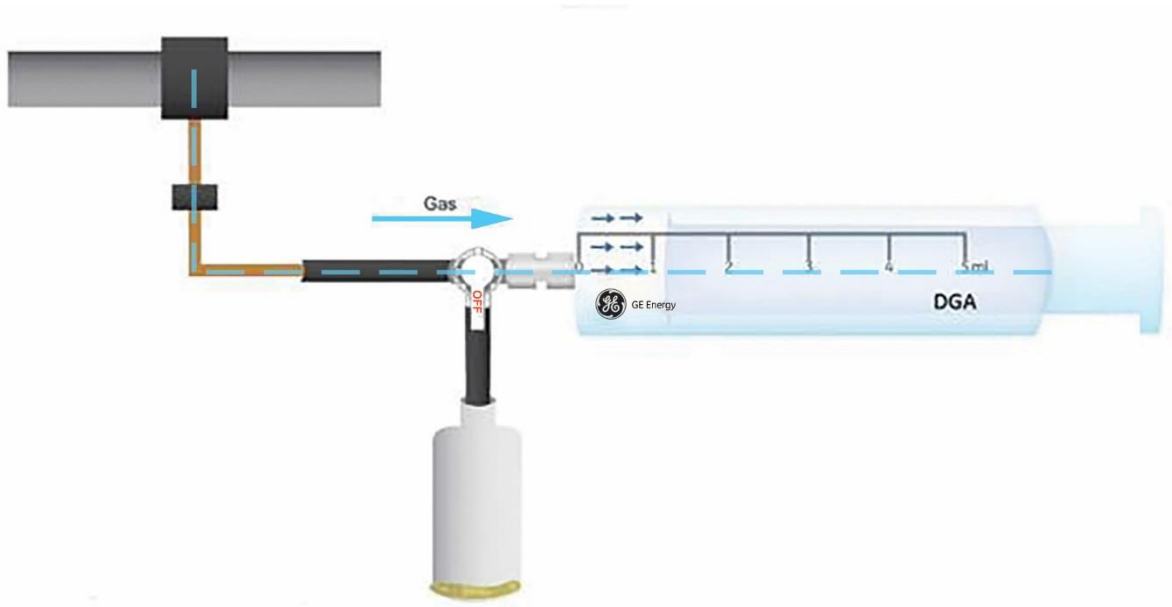


Figure 9-2: Gas fills the syringe

4. When the syringe is filled to the 5 ml mark, turn the three-way stopcock again as shown in Figure 9-3 to seal the gas in the syringe ready for injection into the Transport X².
5. Disconnect the syringe/stopcock from the tubing.
6. Analyse the gas sample immediately or as soon as possible after collecting the sample.

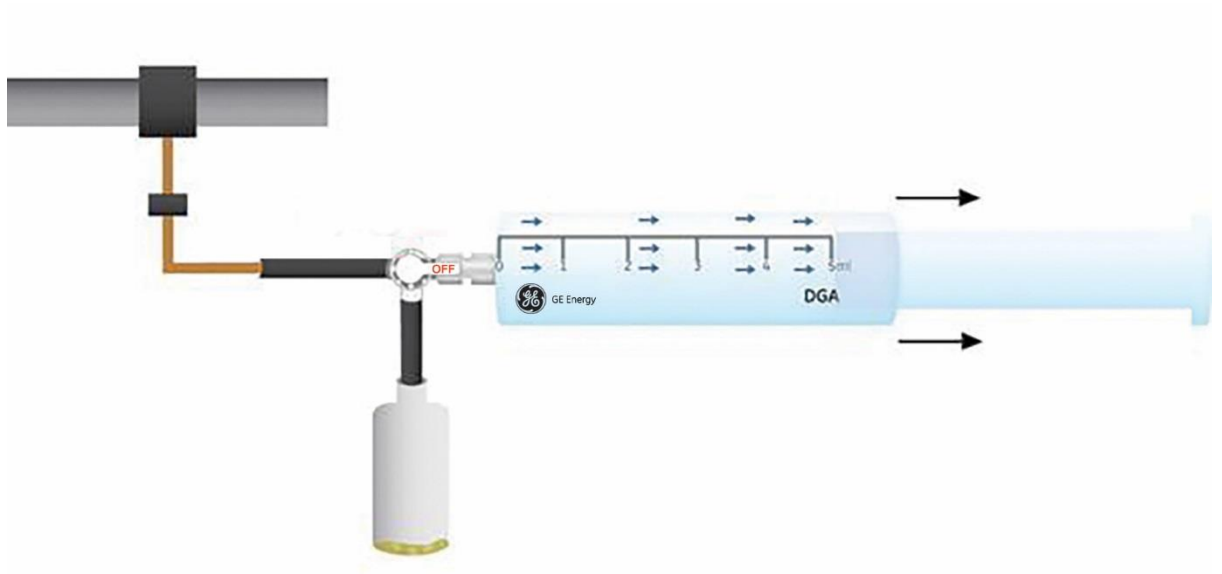


Figure 9-3: Gas sealed in the syringe

9.2 Injection & Measurement

The process is similar to that for an oil sample as already described in Sections 7.3. The first step is to enter all the required sample information to allow the creation of a measurement record, then inject the gas sample and wait for the measurement results. Any differences to the process and procedure for a gas sample are discussed below:

1. Press **New Measurement** from the Main Menu screen and follow the onscreen instructions to select, modify or enter all the information for the sample as previously outlined in Section 7.3.
2. When prompted to select the 'Sampling Point' as shown in Figure 9-4, press **Add New** and use the onscreen keypad to type Buchholz Relay.

New Measurement > Data Input 4/10 > Sampling Point

Buchholz Relay	Type: Transformer
Drain Valve	Location: New City
	Equipment: A12345

Edit Remove

Add New

Back Next Home

Figure 9-4: New Measurement > Input Record (step 4/10) > Sampling Point

3. When prompted to select the Sample Details as shown in Figure 9-5, select **Gas**.
Note: The lower detection limit for gases is 50 ppm.

New Measurement > Data Input 8/10 > Sample Details

Oil Gas

Caution: Lower detection limit for gases is 50ppm

Extraction Temperature 22.0 °C Normalization Temperature 20 °C

Type your comment here

Back Next Home

Figure 9-5: New Measurement > Input Record (step 8/10) > Sample Details

- When all the gas sample information has been selected, modified or entered, the software guides the operator through the testing process. Follow the onscreen instructions as shown in Figure 9-6 to install the sample bottle and lid assembly.

Note: For gas samples, there is no need for a magnetic stirrer.

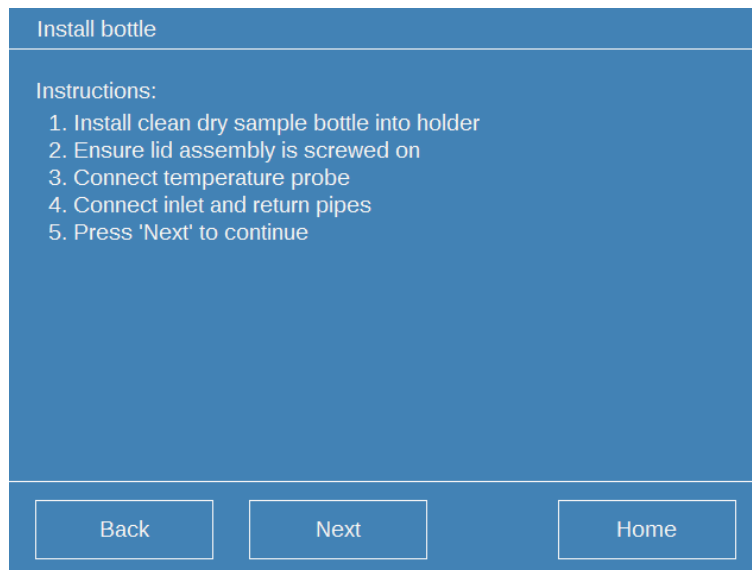


Figure 9-6: New Measurement > Install Bottle - instructions

- When prompted onscreen to inject the gas sample as shown in Figure 9-7, connect the syringe containing the sample gas to the sample bottle via the quick-connect fitting (similar to injecting an oil sample as described in Section 7.3.3).

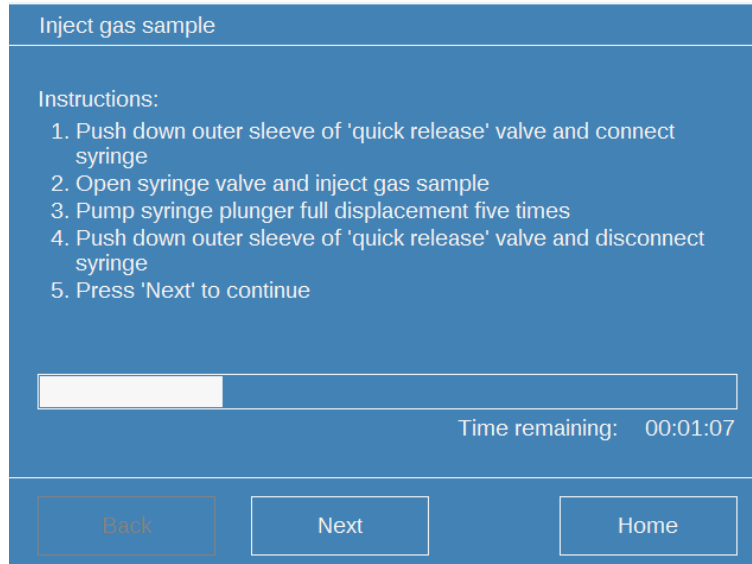


Figure 9-7: New Measurement > Sample Injection - instructions & countdown

- Open the valve on the syringe.
- Depress the plunger fully.
- Leaving the syringe and valve in the same position, draw the plunger back to the 5 ml mark. **Note:** Be careful not to remove it completely.
- Depress the plunger fully again.

10. Pulling down on the outer sleeve of the quick-connect fitting, disconnect the syringe and the quick-connect from the Sample Bottle (similar to disconnecting the syringe when testing an oil sample as described in Section 7.3.3).
11. Press **Next** to continue.

The product measures the dissolved gas concentrations of the supplied gas sample as shown in Figure 9-8.

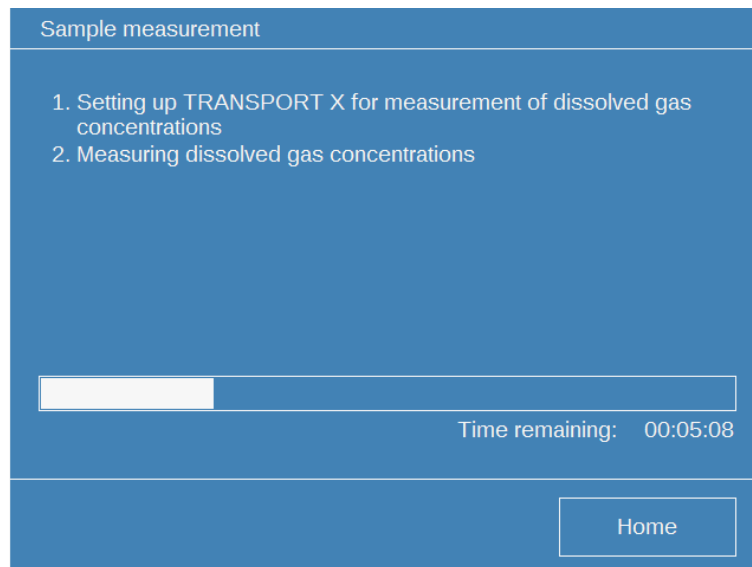


Figure 9-8: New Measurement > Sample Measurement - progress

When the measurements of the gas sample are complete, the results display as shown in Figure 9-9. The gas concentration measurements display on the left with the site equipment details on the right.

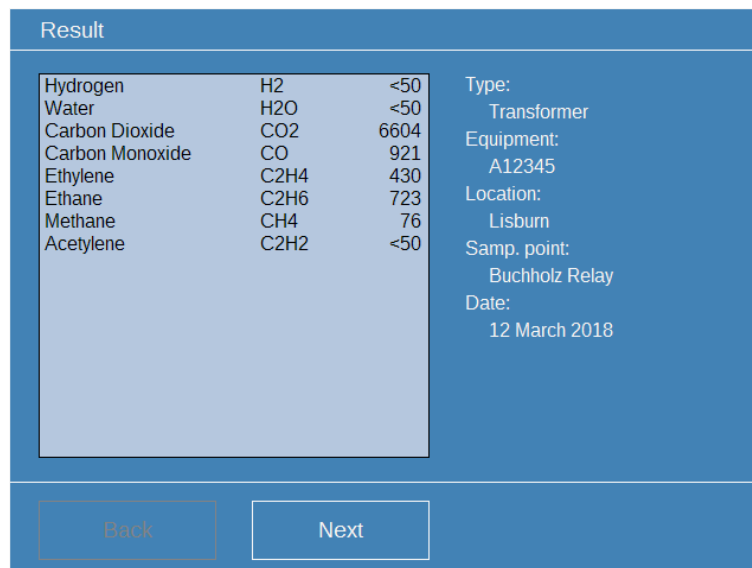


Figure 9-9: Buchholz Gas Relay - Results

Press **Next** to continue. Options exist to print the results, and perform analysis and diagnostics on the results. These options are previously described in Section 7.5.

10 SYSTEM CHECK

The product has a built-in operator-initiated System Gas Check feature to verify that the photo-acoustic spectroscopy (PAS) system is functioning correctly.

Note: The product is inherently very stable so routine calibration of the detector is not required. Recalibration is only necessary in the event of a serious fault or misuse of the instrument. Under these circumstances, recalibration must be performed by GE.

Apparatus to perform this check is contained in the System Check Kit as listed in Table 10-1.

Table 10-1: System Check Kit (KIT00002)

Ref	Item
CASE01003	System Check Case (empty)
VALV01007	Fine Control Valve
TUBE02015	TRX Nafion® tubing
FITT01049	Quick Connect Mini Stem - 1/8 F NPT - Brass
FITT02017	Luer Lock Ring Male 10-32 Nylon
BGAS01001	Canister of System Check Gas
FITT02015	Adapter 1/8 NPT to 10-32 Female Nylon
FITT02010	Tee Reduction Connect
TUBE02019	TRF Viton 1/8 x 3/16 x 1/32

The pressurized gas cylinder contains a mixture of all the target DGA test gases at known concentrations. The tubing with quick-connect assembly is used to connect the gas cylinder to the inlet connector (oil injection port) on the top panel of the product.

Note: The cylinder of gas is non-flammable and non-toxic, but should only be used in a well-ventilated area by trained personnel.

Note: The Lid assembly and bottle are not required.

10.1 Initiate a System Check

The System Check procedure outlined here can be performed as often as desired, but is recommended nominally every three months. This is simply to provide confidence and assurance in the operation of the product. Follow these steps:

From the Main Menu, press **Self Test** as shown in Figure 10-1.

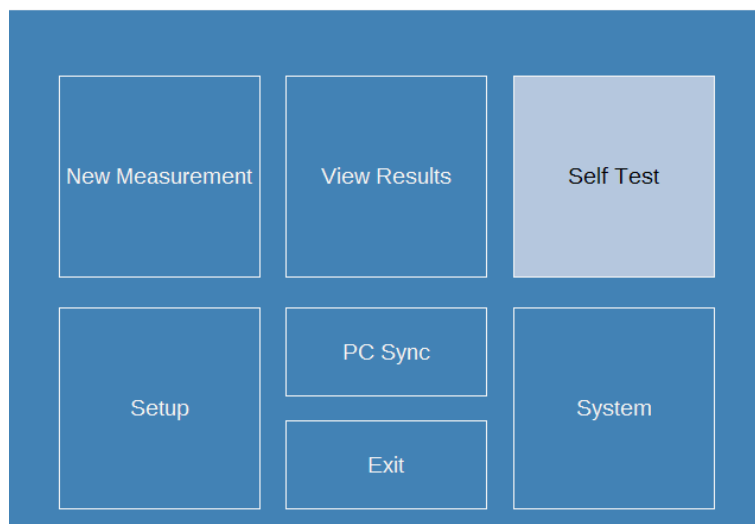


Figure 10-1: Main Menu

From the Self Test screen, press **System Check** as shown in Figure 10-2.

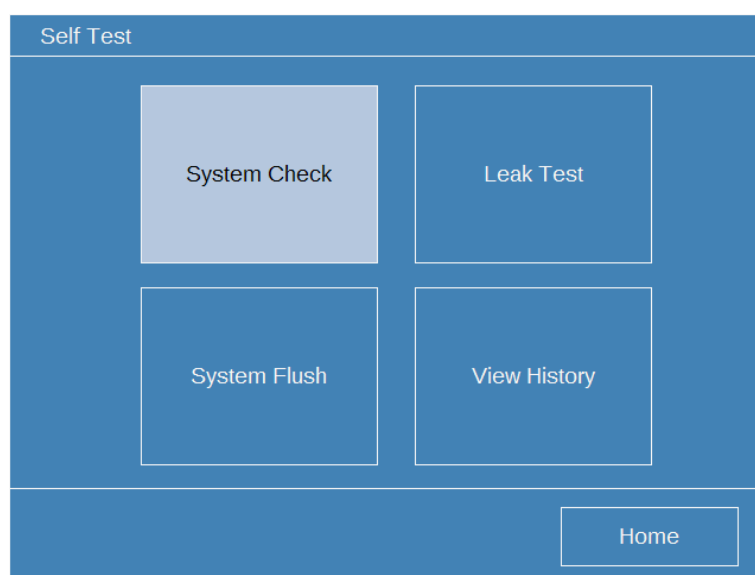


Figure 10-2: Self Test

10.2 Connect & Flush with Air

The 'System Check' Instructions screen displays as shown in Figure 10-3. Follow the onscreen instructions to connect the System Check Kit apparatus as shown in Figure 10-4 and Figure 10-5.

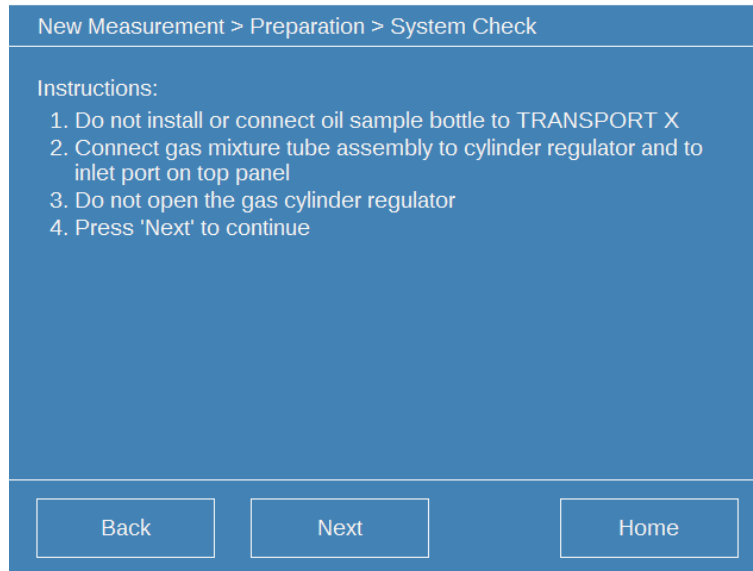


Figure 10-3: System Check - instructions

Connect the Nafion tubing to the cylinder via the gas regulator by pushing the flexible black Viton tubing over the barb connector on the outlet of the clear plastic flow cell as shown in Figure 10-4.

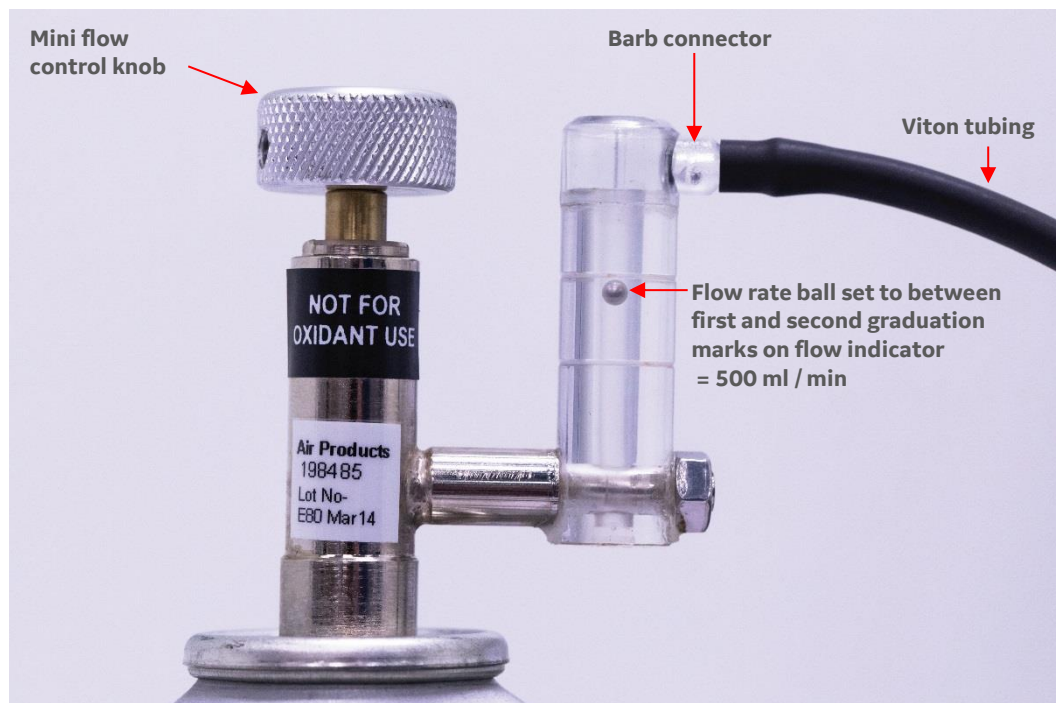


Figure 10-4: Gas cylinder regulator with clear plastic flow cell and Viton tubing connection

Connect the other end of the Nafion tubing, which is fitted with a male quick-release connector, to the top-panel of the product via the female quick-release connector as shown in Figure 10-5.

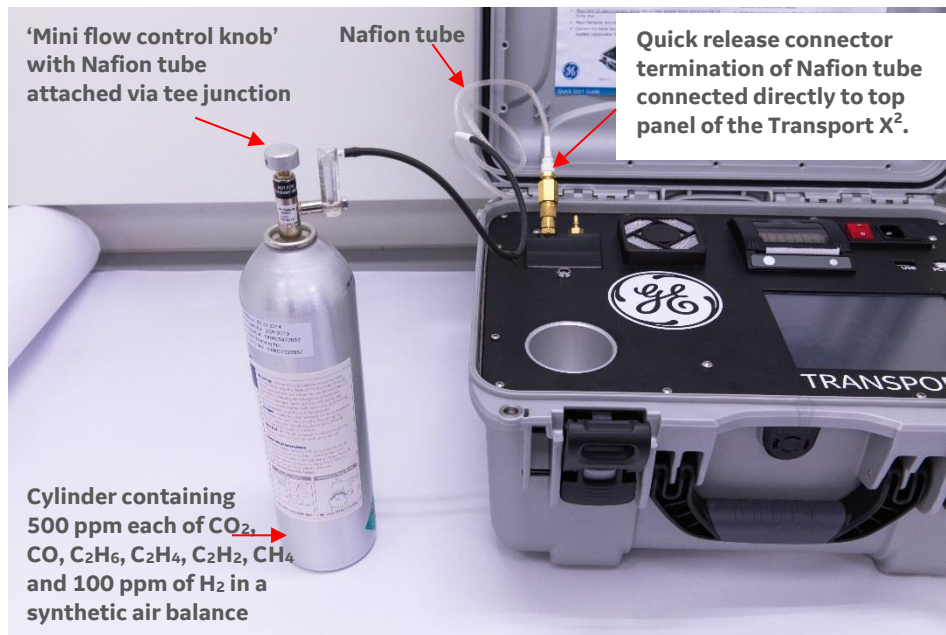


Figure 10-5: Gas cylinder connected to the Transport X² via Nafion tube

Once this equipment arrangement is complete, press **Next**.

The Flushing With Air Progress screen displays as shown in Figure 10-6.

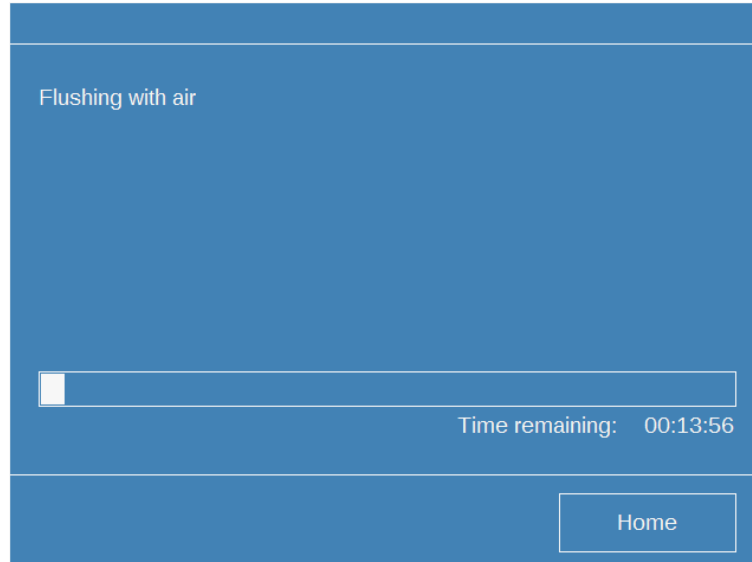


Figure 10-6: System Check - Flushing with air - progress

The air flushing takes approximately 14 minutes and 30 seconds to complete.

10.3 Flush with Test Gas & Disconnect

When the air flushing process is complete, the Inject Sample screen automatically displays as shown in Figure 10-7. Use the 'Mini flow control knob' on the cylinder gas regulator to operate the fine-adjustment control valve. This knob should be turned slowly in an anticlockwise direction until the desired flow rate is achieved. Set the flow rate to the product at 500 ml/minute (i.e. approximately a quarter to half of the maximum flow rate). The correct flow rate is indicated by the small metal ball in the flow channel being lifted to the point where it is between the two graduation lines in the clear plastic flow cell as shown in Figure 10-4.

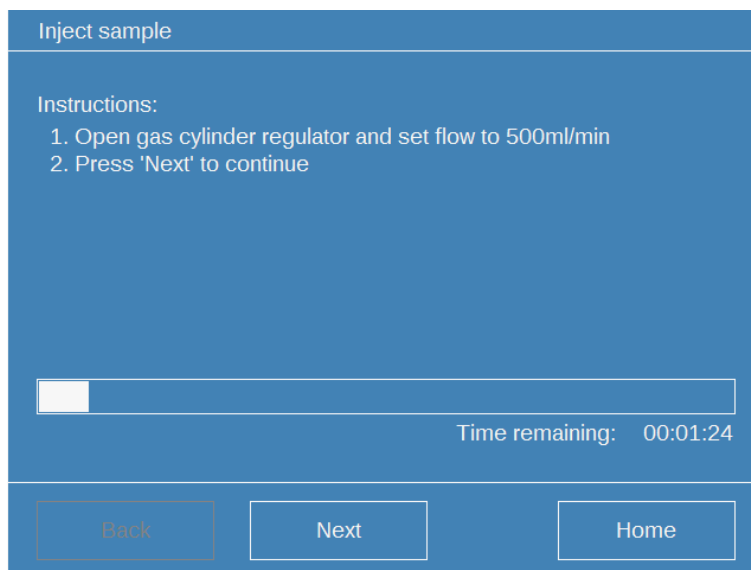


Figure 10-7: System Check - Inject Sample

The operator has only a limited period of 1 minute and 30 seconds to set up the required gas flow to the product. During this period, the product beeps continuously. Press **Next** when the correct gas flow rate is achieved.

The 'Flushing With Gas Mixture Progress' screen displays as shown in Figure 10-8.

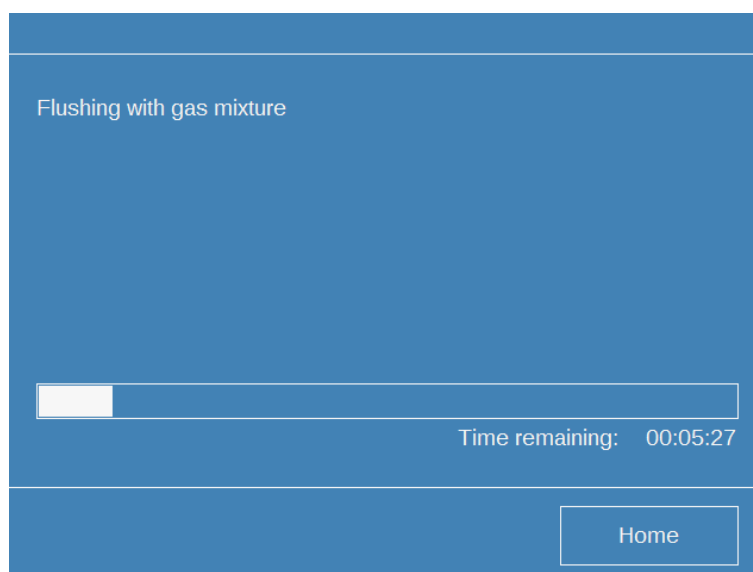


Figure 10-8: System Check - Flushing with Gas Mixture

After approximately 2 minutes of flushing with the test gas, the product starts making gas concentration measurements on the test gas and automatically displays the 'Measuring Gas Mixture' progress screen as shown in Figure 10-9.

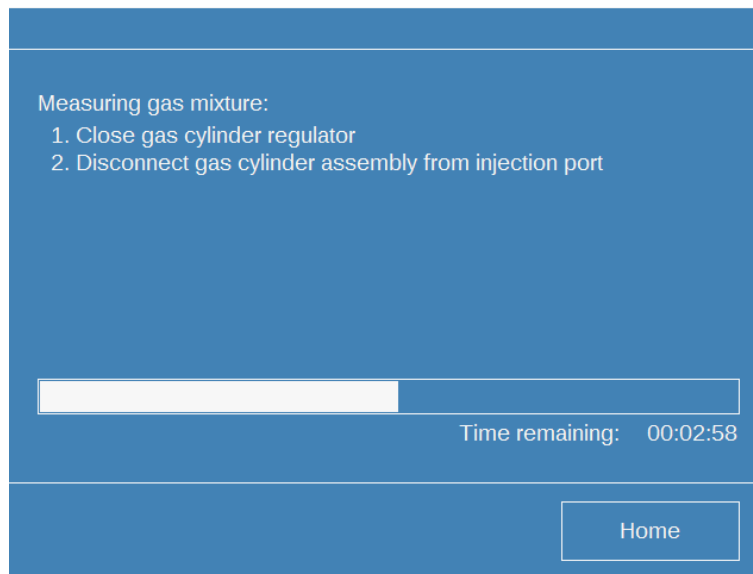


Figure 10-9: System Check – Measuring Gas Mixture

The process of making the gas concentration measurements on the test gas takes approximately 3.5 minutes. Afterwards, close the gas regulator valve on the gas cylinder and disconnect the Nafion gas supply tube from the injection port on the top panel of the product.

When all the measurements have been made, the screen changes to the 'System Check' screen as shown in Figure 10-10 and repeats the same closure instructions as a reminder to avoid gas wastage.

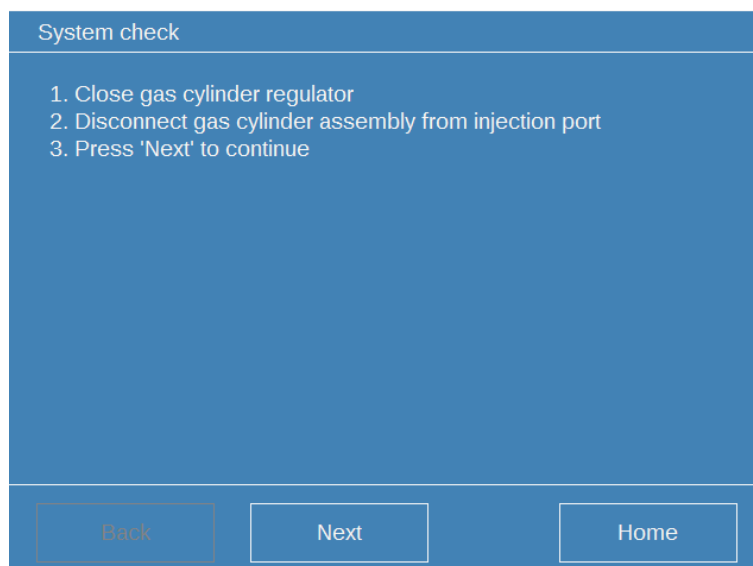


Figure 10-10: System Check – Complete

Press **Next** to see the System Check results.

10.4 System Check Results

If the product fails the System Check, the following screen displays as shown in Figure 10-11. Press **View Details** to see the test gas measurement details.

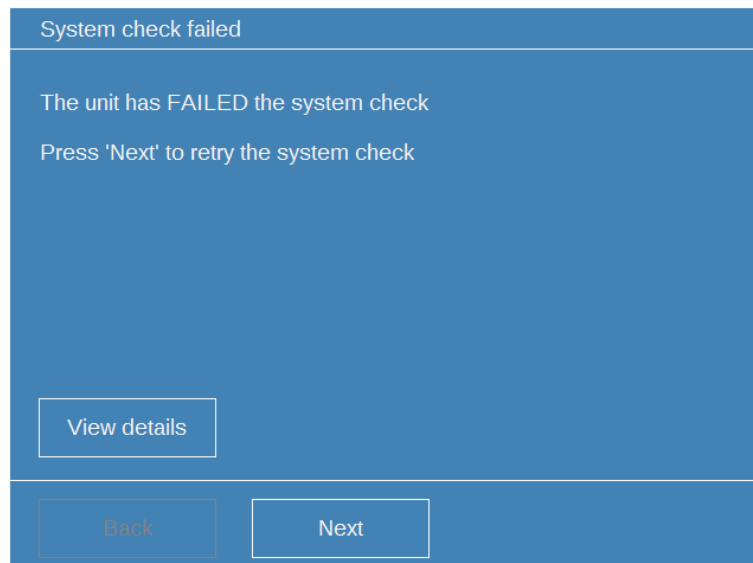


Figure 10-11: System Check Failed

Details of the System Check display as shown in Figure 10-12. The gas concentration measurements display on the left with the site equipment details on the right.

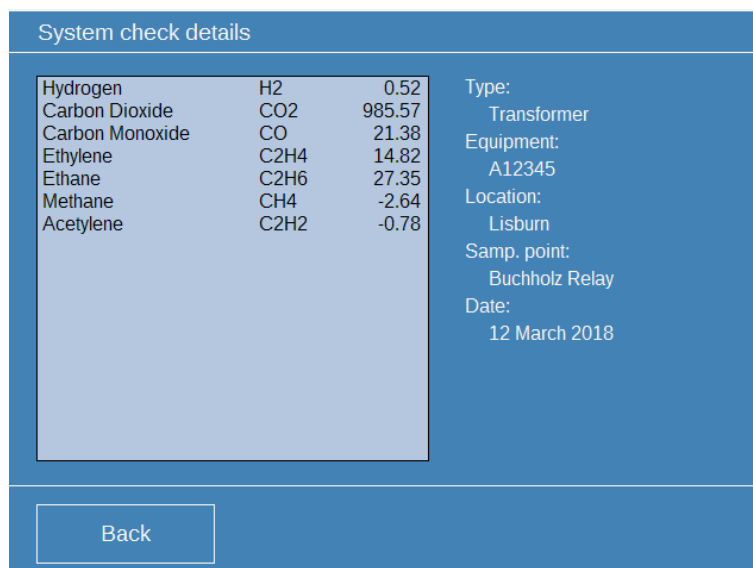


Figure 10-12: System Check Details

Press **Back** and in the event of a fail result, press **Next** to repeat the System Check.

Before repeating the test, ensure there is no obstruction in the Nafion tube assembly. This can be checked as follows:

1. Connect the Viton end of the Nafion tube to the barb connector on the clear plastic flow cell that is attached to the gas cylinder regulator.
2. Block the side arm of the Tee junction in the Nafion tube.
3. Use the 'Mini flow control knob' to set the flow to 500 ml/min.

4. Place an obstruction momentarily over the open end of the Nafion tube and note the effect this has on the flow rate.
 - If the flow rate drops, but does not fall to zero, this indicates that there is still an open channel in the Nafion tube.
 - Ensure the flow remains steady at 500 ml/min or more throughout the re-test by observing the position of the flow indicator ball throughout a second test.

If the second test also results in a fail result, re-test again. After three consecutive fail results, stop using the product and contact GE.

If the product passes the system check, the following screen displays as shown in Figure 10-13. Press **Next** to view the results.

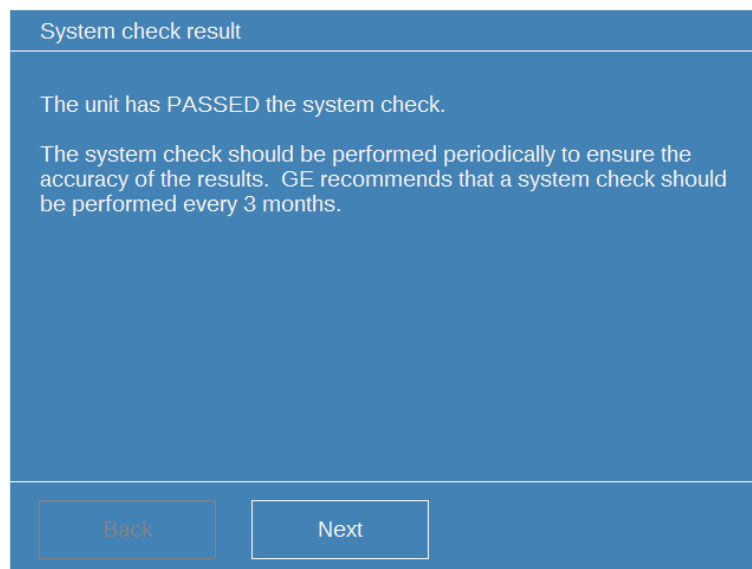


Figure 10-13: System Check Passed

Details of the System Check display as shown in Figure 10-14. The gas concentration measurements display on the left with the site equipment details on the right.

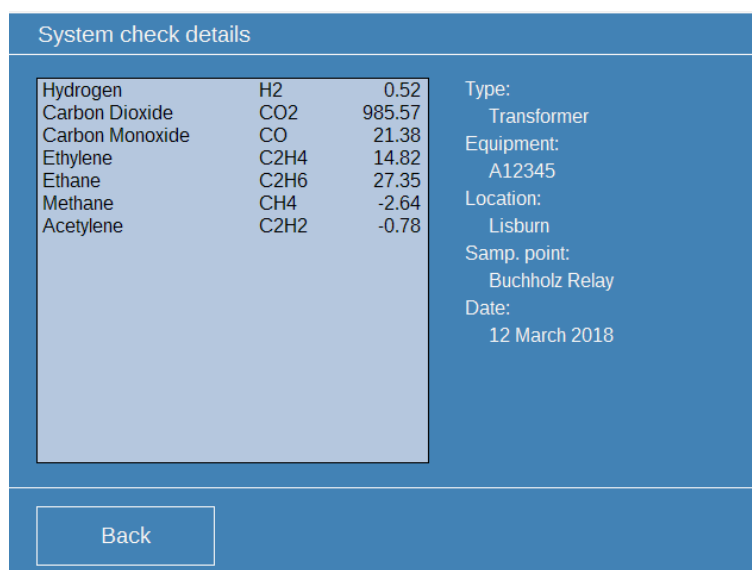


Figure 10-14: System Check Details

A pass means that the measured gas concentration results are within the $\pm 15\%$ of the true gas concentrations of the test gas.

Note: The gas cylinder contains 12 litres of gas and is pressurized to 300 psi at 20 °C when full. Each test consumes at least 1 litre of gas, so a full cylinder should allow up to twelve system checks.

Note: The gas mixture has a shelf life of two years from the date of manufacture (marked on the bottom of the cylinder).

Note: The gas cylinder should be disposed of or recycled once empty.

10.5 Hydrogen Exclusion

A molecularly balanced gas compound, such as hydrogen (H_2) cannot be measured using PAS and is instead measured using a tin dioxide (SnO_2) semiconductor that has a low conductivity in clean air. The tin dioxide sensor can result in H_2 consumption due to the nature of the System Gas Check, so this may, under certain circumstances, incorrectly trigger an error with the H_2 sensor.

For this reason, the system gas check does not measure H_2 as it would not be representative, thereby restricting testing to the six photoacoustic gases.

Note: During normal product operation, the functionality to measure H_2 remains.

11 SYSTEM CONNECTIVITY

Transport X² provides external connectivity via two USB ports on the top panel as shown in Figure 11-1 (see Appendix A for connecting to a PC). All connectivity is seamless without the need for third-party drivers.

Note: Microsoft ActiveSync is no longer required.



Figure 11-1: USB ports

- **USB:** The left-most port is a standard Type A USB 2.0 port for the purposes of downloading measurement data to a USB pen drive, retrieving system log files, making a full system backup or performing firmware upgrades.
- **PC SYNC:** The right-most port is a Type B USB 2.0 port for directly connecting the Transport X² to a PC using the supplied USB cable to allow measurement data to be downloaded to the Perception software suite for further analysis and trending if required (see Appendix B for downloading data into Perception).

11.1 Download data to USB Pen Drive

System logging is enabled by default. To download log files or measurement data to a USB pen drive, insert a USB pen drive into the Type A USB port and press **PC SYNC** on the Main Menu. If the USB pen drive is recognised, a message displays as shown in Figure 11-2.

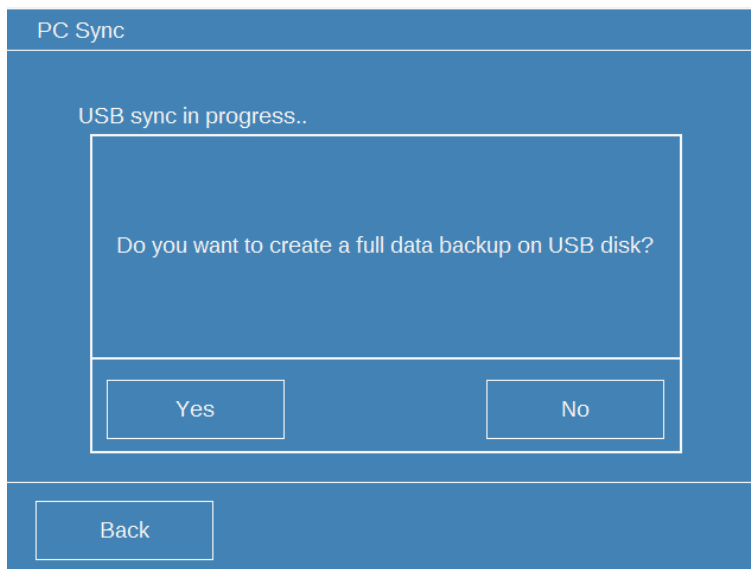


Figure 11-2: Sync - full data backup

Press **Yes** to perform a full data backup (including system log files) and wait for the syncing to complete as shown in Figure 11-3.

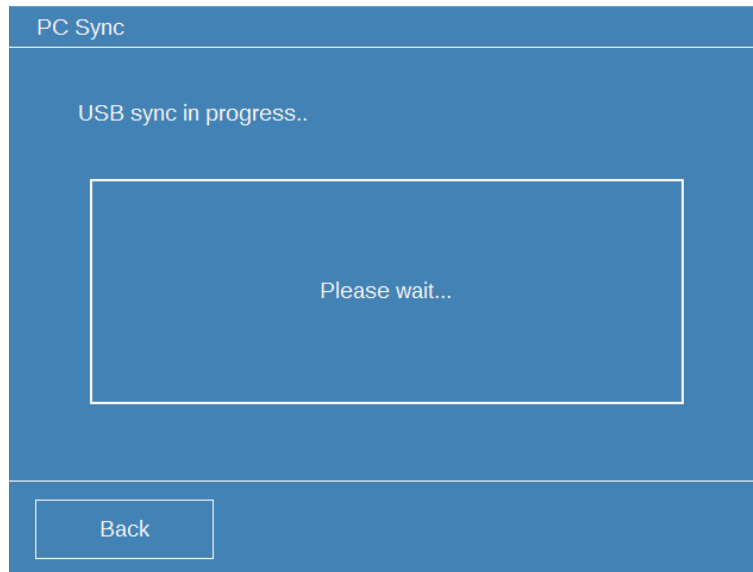


Figure 11-3: Sync - in progress

Press **Back** to return to the Main Menu.

Note: Measurement data and log files can also be downloaded directly from a unit that is connected to Perception (see Appendix B).

11.2 Retrieve Results & Log Files

Remove the USB pen drive from the Transport X² and explore the folder hierarchy of the full backup. Inside the 'TransportX' folder are two subfolders:

- 'Customer Results' – contains all the measurement details in a file named pga.csv.
- 'Service Data' – contains all the required service logs.

When requested, email the 'Service Data' folder containing the log files to GE for inspection.

Note: Measurement data and log files can also be downloaded directly from a unit that is connected to Perception (see Appendix B).

11.3 Upgrade Firmware

GE periodically updates the Transport X² firmware. If a new version of firmware is released, copy the firmware to a USB pen drive and follow these steps:

1. Insert the USB pen drive into the Type A USB port and press **PC SYNC** on the Main Menu. If the USB pen drive is recognised, a message displays as shown in Figure 11-4.

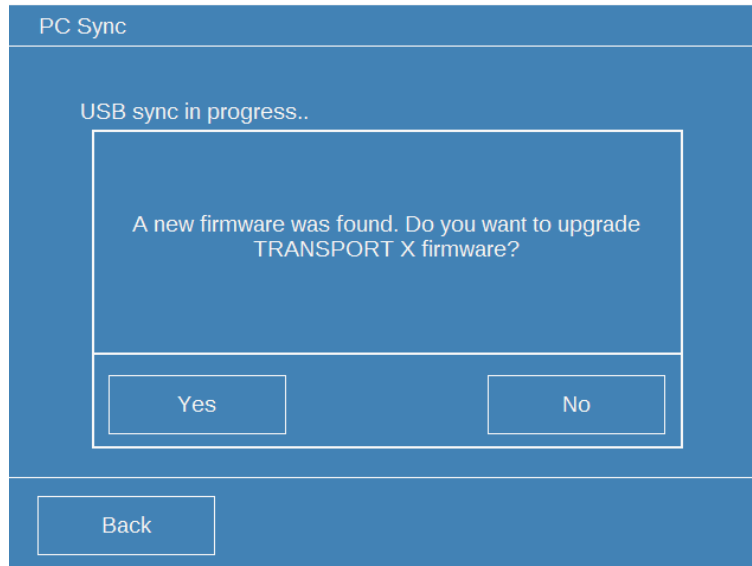


Figure 11-4: Firmware Upgrade - start

2. Press **Yes** to proceed with the firmware upgrade. The various phases of the upgrade are listed as they occur and a bar shows the progress. If successful, the **Start Transport X** button displays as shown in Figure 11-5.

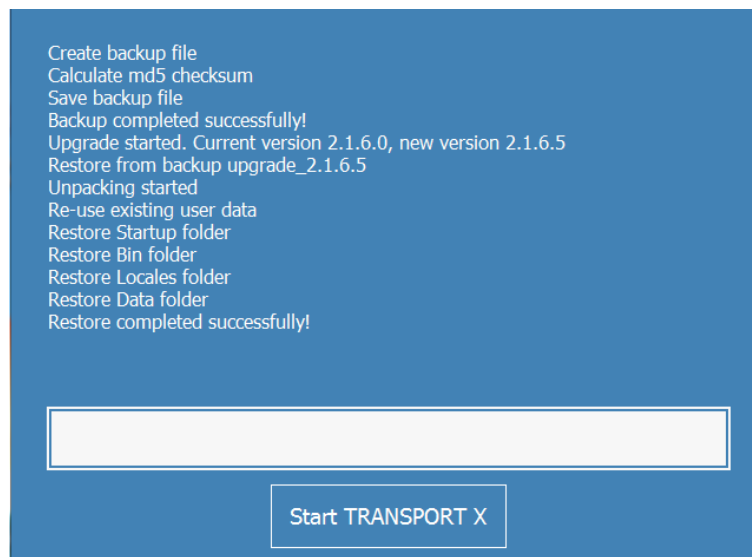


Figure 11-5: Firmware Upgrade - complete

3. Press **Start Transport X** to restart the product and use the new firmware.

12 BOTTLE LID ASSEMBLY EXCHANGE

Each Transport X² is assigned a unique bottle lid assembly in the factory. These cannot normally be exchanged between units since the bottle lid assembly temperature probe includes a capacitive moisture sensor that has been specifically configured for the unit. If a new bottle lid assembly must be used, it is essential to reconfigure the unit with the new calibration factors associated with the new bottle lid assembly capacitive moisture sensor.

The settings that must be modified in the product to permit a change of bottle lid are:

- Slope (*kw*)
- Zero Offset (*zw*)

To adjust these settings, follow these steps:

1. From the Main Menu screen as shown in Figure 12-1, press **Setup**.

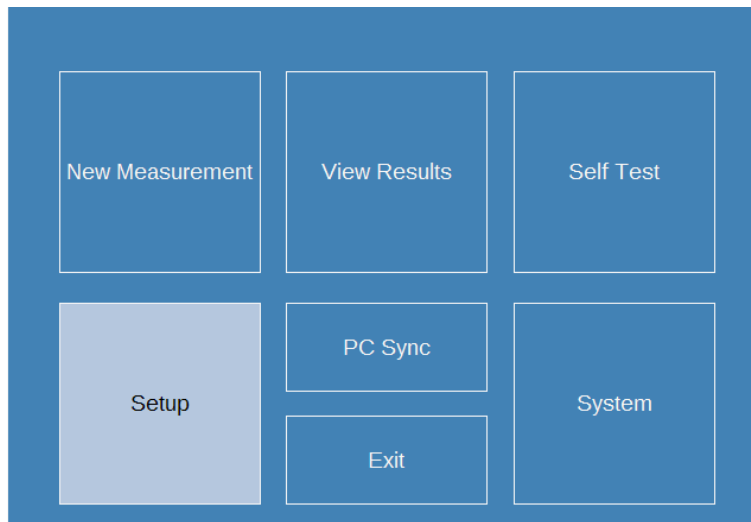


Figure 12-1: Main Menu

2. The Setup screen displays as shown in Figure 12-2. Press **Bottle Lid**.

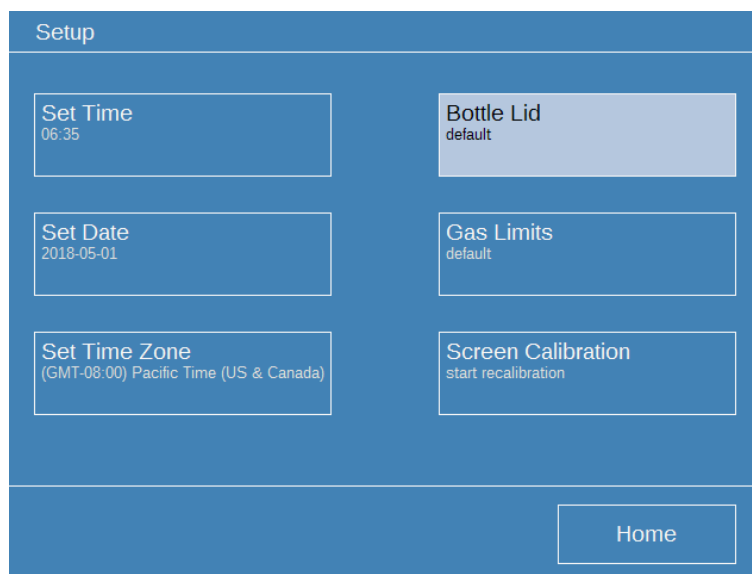


Figure 12-2: Setup > Bottle Lid

The Select Moisture Sensor screen lists all the bottle lid moisture sensor names on the left as shown in Figure 12-3. **Note: 'default' is the initial name of the supplied bottle lid.**

The selected bottle lid's corresponding calibration factors for the moisture sensor display on the right.

Options exist to add a new bottle lid, remove an existing bottle lid (currently disabled as at least one needs to remain) or edit the existing bottle lid.

Note: The default bottle lid cannot be removed, but can be modified.

3. Press **Add New** to add a new bottle lid's details or **Edit** to modify the existing bottle lid's details as shown in Figure 12-4.

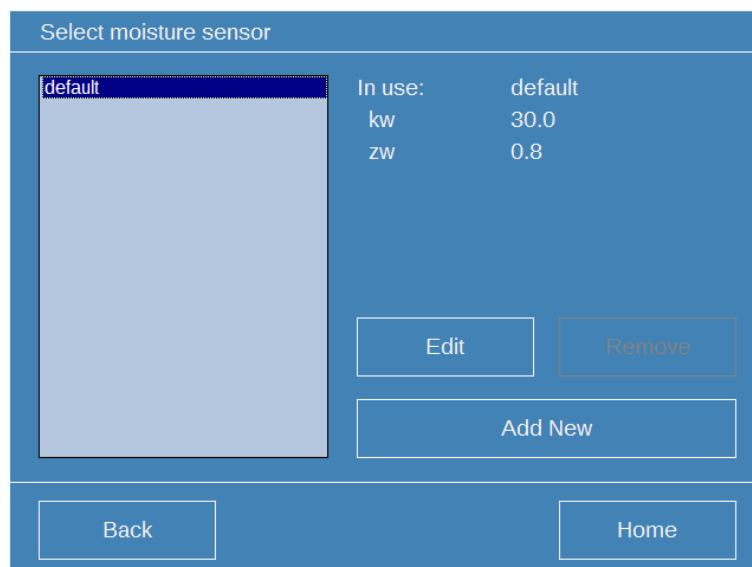


Figure 12-3: Select Moisture Sensor - calibration details

Use the onscreen keyboard to select the relevant fields and modify the current calibration factors for the default bottle lid as shown in Figure 12-4.

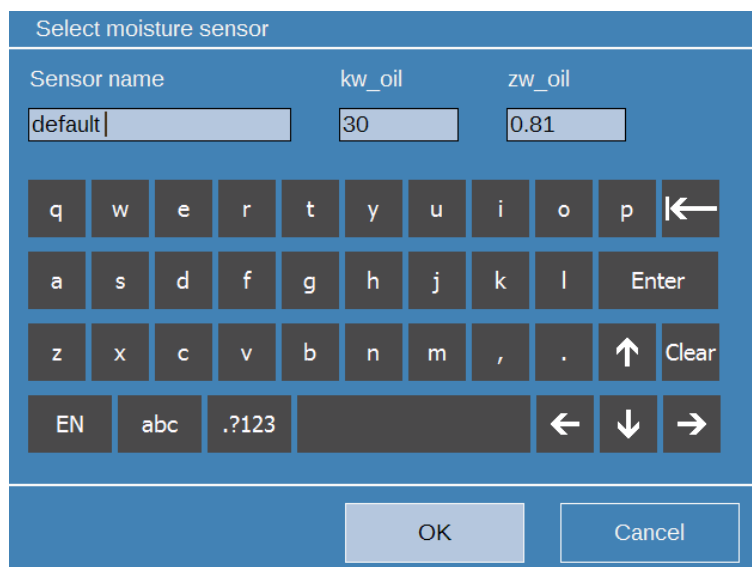


Figure 12-4: Select Moisture Sensor - keyboard - modifying calibration details

Or use the onscreen keyboard to supply a new name and corresponding calibration factors for the new bottle lid as shown in Figure 12-5.

The screenshot shows a blue-themed interface titled "Select moisture sensor". At the top, there are three input fields: "Sensor name" containing "Sensor XYZ", "kw_oil" containing "25", and "zw_oil" containing "0.75". Below these fields is a full QWERTY onscreen keyboard with navigation arrows. At the bottom of the screen are two buttons: "OK" and "Cancel".

Figure 12-5: Select Moisture Sensor – keyboard - new calibration details

Therefore, select an existing bottle lid name or modify an existing bottle lid’s set of calibration factors (if a previous lid assembly is being reused) or enter the details of a new bottle lid.

Note: If it is intended to switch back to the original lid assembly in the future, create a new bottle lid name rather than edit the existing calibration factors associated with the original bottle lid.

4. After the new calibration factors have been entered, press **OK** to accept the new settings and return to the ‘Select Moisture Sensor’ screen.

The Select Moisture Sensor screen refreshes to show the updated calibration factors for the new bottle lid as shown in Figure 12-6.

The screenshot shows the "Select moisture sensor" screen after the changes. On the left is a list with "default" and "Sensor XYZ" (highlighted). On the right, the "In use:" section displays "Sensor XYZ" with "kw" set to "25.0" and "zw" set to "0.8". Below this are "Edit" and "Remove" buttons, and an "Add New" button. At the bottom are "Back" and "Home" buttons.

Figure 12-6: Select Moisture Sensor – new calibration details

5. After the new calibration factors have been selected or entered, press **Home** to return to the Main Menu as shown in Figure 12-7.

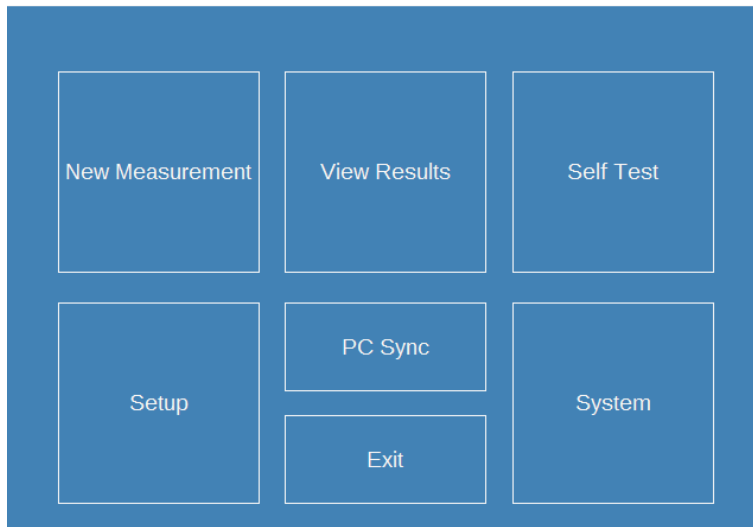


Figure 12-7: Main Menu

The operator may now proceed to use the new bottle lid calibration factors for all future measurements.

13 TROUBLESHOOTING

Table 13-1 lists the product error codes, descriptions, categories and recommended responses.

Table 13-1: Error Codes

Error Code	Logfile Text	User Display Text	Condition	1st Response	2nd Response
0	H ₂ sensor malfunction	Hardware Error - Contact ge4service@ge.com	HW Warning	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
1	Hydrogen atmospheric contamination	Hydrogen atmospheric contamination	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
2	Humidity too low	Ambient Humidity too low	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
3	Humidity too high	Ambient Humidity too high	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
4	Sample H ₂ O close to saturation	Water is close to saturation and will have larger margin for error	GAS Caution	Consider alternative method for accurate moisture measurement of this oil sample	N/A
5	General malfunction / CO ₂ measurement malfunction	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
6	Atmospheric contamination / Ambient CO ₂ too high	Atmospheric contamination / Ambient CO ₂ too high	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
7-8	CO atmospheric contamination	CO atmospheric contamination	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback

9-10	Atmospheric hydrocarbon contamination	Atmospheric hydrocarbon contamination - results could be affected	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
11-16	Atmospheric hydrocarbon contamination	Atmospheric hydrocarbon contamination - results could be affected	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
17-18	Atmospheric hydrocarbon contamination / Contaminated sample container	Atmospheric hydrocarbon contamination / Contaminated sample container	GAS Caution	Change filters, ventilate room, perform system flush and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
19	Sample contamination	Sample contamination - results could be affected	GAS Caution	Thoroughly clean bottle, run system flush and collect and test a fresh sample	Send Transport X ² Logfile to GE - clean bottle and perform system flush before testing next sample
20-23 & 25	Malfunction in pressure sensor	Hardware Error - Contact ge4service@ge.com	HW Warning	Check all gas line connection, change filters and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
24	Filter Blockage / bottle leak	Possible bottle or filter leak. Change In-line filters	HW Caution	N/A	N/A
26	Recommended filter usage exceeded	Recommended filter usage exceeded. Change in-line filters	HW Caution	Change filters and confirm change during next test	N/A
27	Oil too cold	Oil too cold	GAS Caution	Allow oil to warm up to room temperature	Send Transport X ² Logfile and description of circumstances to GE for feedback
28	Cell temperature too low	Hardware Error - Contact ge4service@ge.com	HW Warning	Allow Transport X ² to warm up	Send Transport X ² Logfile and description of circumstances to GE for feedback

29	Cell temperature too high	Hardware Error - Contact ge4service@ge.com	HW Warning	Move to a cooler environment and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
30	Source temperature too low	Hardware Error - Contact ge4service@ge.com	HW Warning	Move to a warmer environment and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
31	Source temperature too high	Hardware Error - Contact ge4service@ge.com	HW Warning	Move to a cooler environment and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
32	Cell temperature too low	Hardware Error - Contact ge4service@ge.com	HW Warning	Move to a warmer environment and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
33	Cell temperature too high	Hardware Error - Contact ge4service@ge.com	HW Warning	Move to a cooler environment and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
34 & 35	IR source malfunction	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
36 & 37	Chopper error	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
38	Supply voltage too low	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
39	Supply voltage too high	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and retry	Send Transport X ² Logfile and description of circumstances to GE for feedback
40	Strong non-hydrocarbon interference	Strong non-hydrocarbon interference in sample- results not reliable	GAS Warning	Thoroughly clean bottle, run system flush and collect and test a fresh sample	Send Transport X ² Logfile and description of circumstances to GE for feedback
41	Some non-hydrocarbon interference	Some non-hydrocarbon interference in	GAS Caution	Thoroughly clean bottle, run system flush and collect and test a fresh sample	Send Transport X ² Logfile and description of circumstances to GE for feedback

		sample - results could be affected			
42	Sample H ₂ O did not reach equilibrium	Moisture did not reach equilibrium. Water result has larger margin for error	GAS Caution	Consider alternative method for accurate moisture measurement of this oil sample	N/A
43	Microphone has stuck	Hardware Error - Contact ge4service@ge.com	HW Warning	Reboot Transport X ² and try again	Contact your GE representative if previous response failed to resolve the issue

The TRANSPORT X² is installed in the same manner as any plug and play device attached to a PC. The USB connection is facilitated by the Remote Network Driver Interface Specification (RNDIS), included with Windows 7 and later. When the Transport X² is connected to the Perception PC, Windows 7 automatically searches for a suitable driver. If for any reason the driver fails to install automatically, follow these steps (described using Windows 7) to manually reinstall it on the Perception PC.

1. Right click **Computer** and select **Manage**. In Computer Management, select **System Tools** > **Device Manager** to see a list of devices currently connected to the Perception PC. Select **Other devices** and look for the **Kelman TRANSPORT X (RNDIS)** entry. If there is an issue with the driver, the device icon includes an exclamation mark.

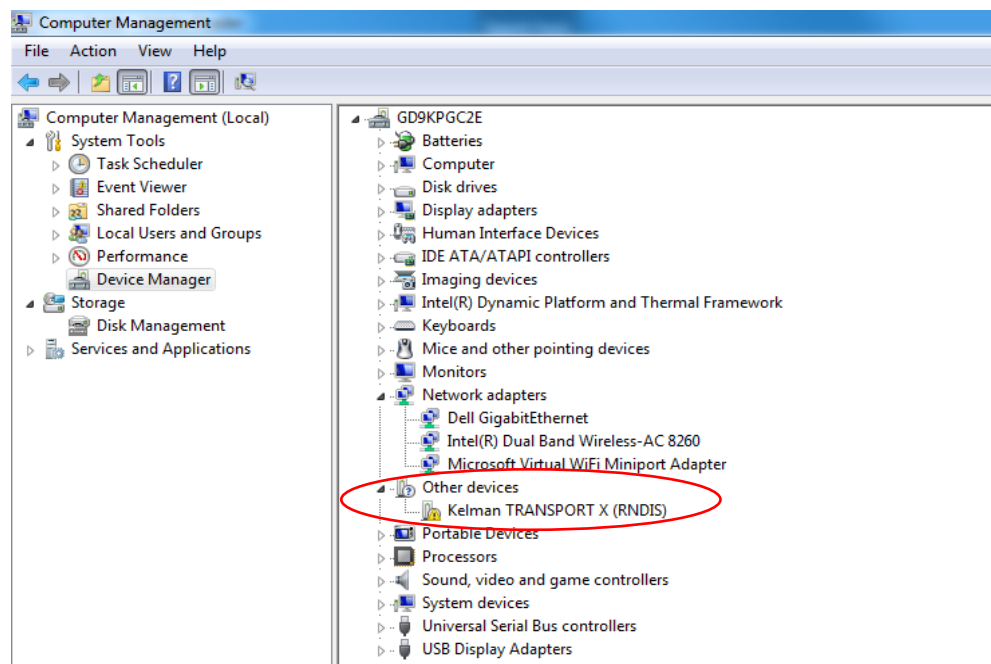


Figure A-1: Computer Management > Device Manager > Other devices

2. Right click **Kelman TRANSPORT X (RNDIS)**, select **Update Driver Software...**, select **Browse my computer for driver software**.

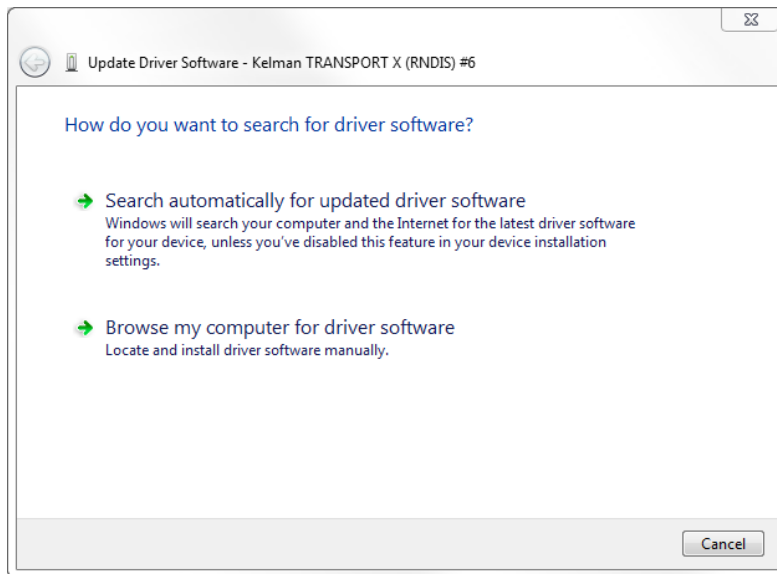


Figure A-2: Update Driver Software

3. Select **Let me pick from a list of device drivers on my computer**, select **Remote NDIS Compatible Device** and click **Next**.

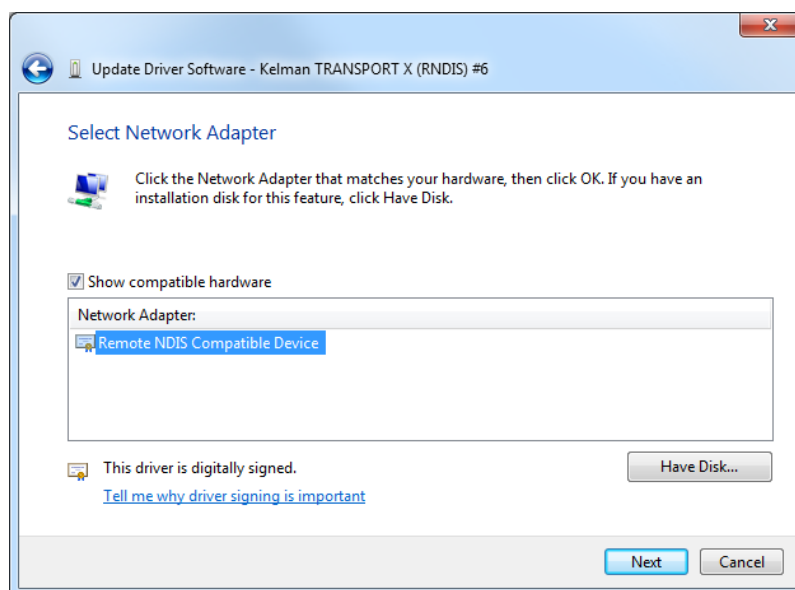


Figure A-3: Remote NDIS Compatible Device

4. The RNDIS driver installation process is now complete. Click **Close**.

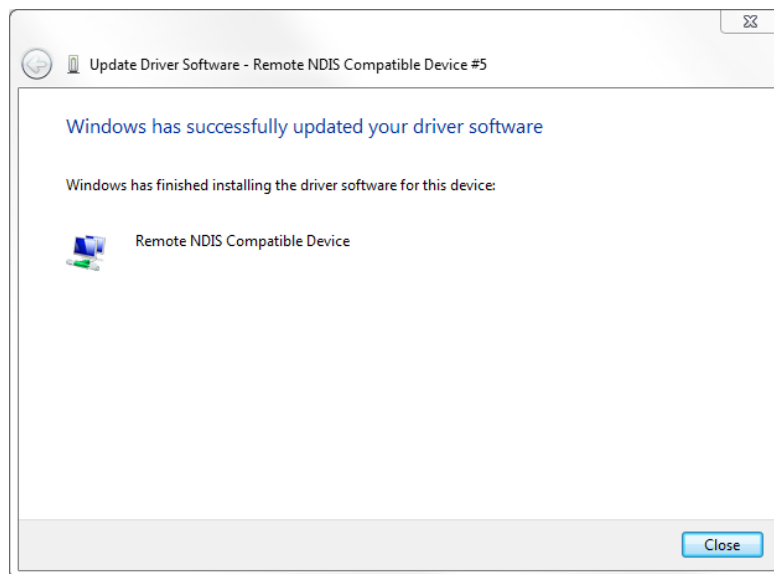


Figure A-4: Update Driver Software – Success

The Kelman TRANSPORT X (RNDIS) driver is now ready for use.

Note: RNDIS is designed to emulate a network connection and is found under the Network adapters grouping.

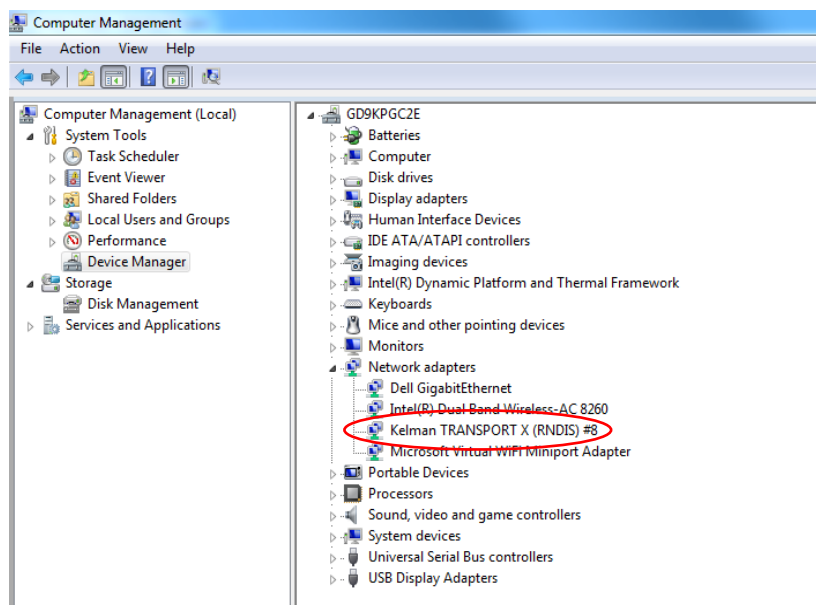


Figure A-5: Computer Management > Device Manager > Network adapters

Appendix B Download Transport X² data to Perception

The Transport X² provides seamless connectivity via USB cable to the Perception software suite without the need for third-party software, such as Active Sync or WMDC. Follow the steps outlined in Appendix A to connect the Transport X² to a Windows 7 or later PC. Once the connection is established, the device is represented in Perception's Asset Explorer and appears above the root node in the Asset Hierarchy as shown in Figure B-1.

Note: The asset is automatically detected about 30 seconds after the device is connected to a PC with Perception Desktop.

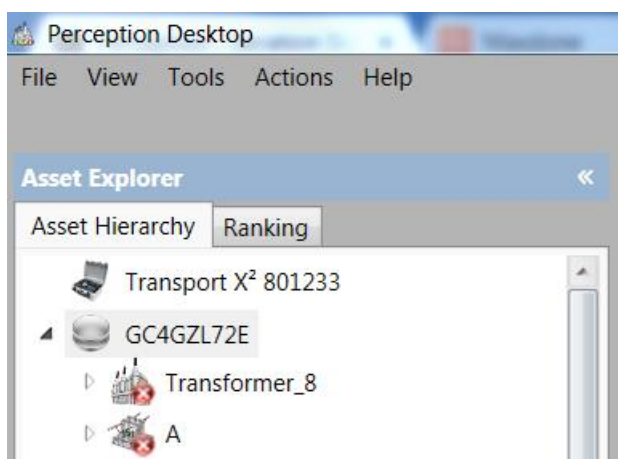


Figure B-1: Asset Hierarchy showing Transport X²

The Properties tab contains some basic information about the device such as the serial number as shown in Figure B-2. To establish communication with the device, the connection needs to be confirmed on the device side. From the Transport X² touchscreen Main Menu, press **PC Sync**.

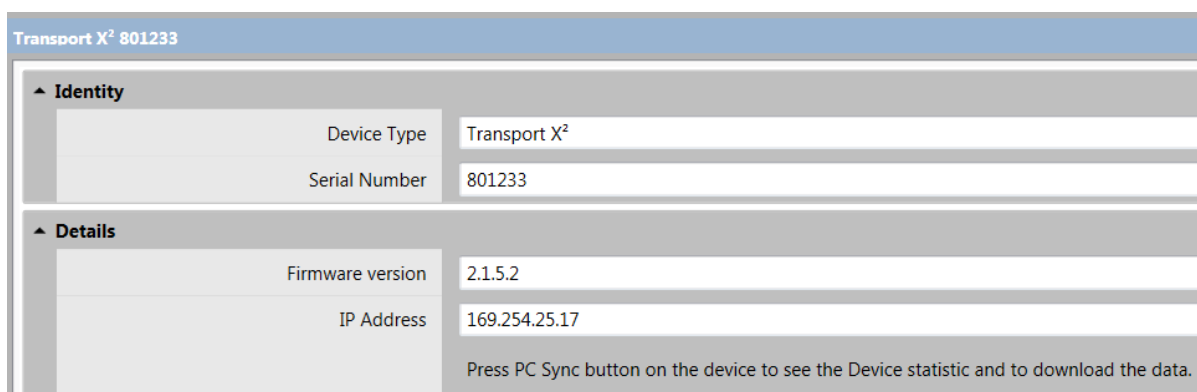


Figure B-2: Transport X² Properties tab – before communication

The Properties tab details additional sections (Statistics & Measurements) as shown in Figure B-3.

The screenshot displays the 'Transport X² 801233' Properties tab. It is organized into four expandable sections:

- Identity:** Device Type (Transport X²), Serial Number (801233)
- Details:** Firmware version (2.1.5.2), IP Address (169.254.25.17)
- Device Statistics:** Number of Transformers (4), Number of Transformer Measurements (5), Filter Status (Ok), Service Required (Ok)
- Last Transformer Measurement Details:** Timestamp (11/01/2018 18:18), Equipment (MXB), Serial number (1), Oil Type (Mineral Oil)

Figure B-3: Transport X² Properties tab - after communication

If new measurements are detected after successful connection to a PC, the user is advised to download the data as shown in Figure B-4 (or this action can be performed later as described below).

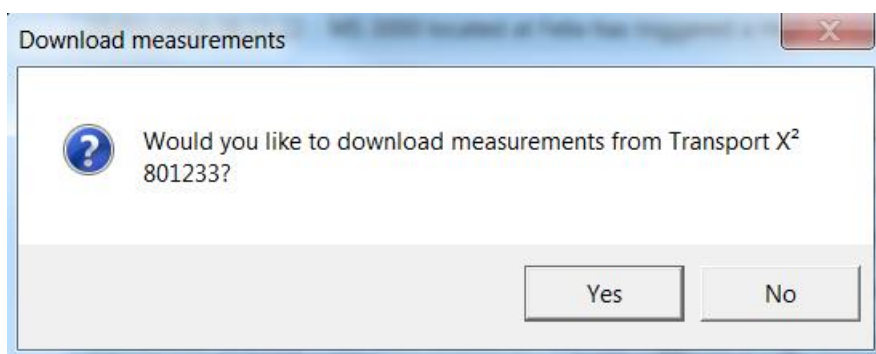


Figure B-4: Transport X² Download measurements message

Right click on the Transport X² asset to see the available options as shown in Figure B-5.

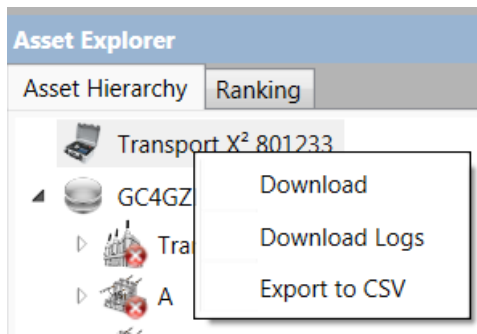


Figure B-5: Transport X² options

- **Download:** retrieves all measurements stored on the device and creates appropriate transformer nodes in the asset tree (or adds additional information to existing nodes based on serialnum / equipnum id).
- **Download Logs:** retrieves debugging and sustaining information from the device to be used by service engineers.
- **Export to CSV:** export all Transport X² data to a CSV file to maintain compatibility with a legacy requirement. *Note: When exporting to CSV, the file is automatically adjusted to the regional settings on the local machine.*

The Transport X firmware is embedded with certain components covered by open source software licenses or the Microsoft Public License. Rights of use are granted by the respective rights holders according to the respective applicable license texts as outlined below. This appendix cites the relevant copyright notices and the rights of use.

C.1 OPENNETCF SMART DEVICE FRAMEWORK

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