HYCAL

User Manual V2.7

Certificate No. 469

Telephone: (01785) 220638 Facsimile: (01785) 214073 E-mail: enquiries@emclimited.co.uk
Registered Office, Unit 2, Brindley Close, Tollgate Industrial Estate, Stafford ST16 3SU.
Registered in England No. 2795460.

Contents

Telephone: (01785) 220638 Facsimile: (01785) 214073 E-mail: enquiries@emclimited.co.uk
Registered Office, Unit 2, Brindley Close, Tollgate Industrial Estate, Stafford ST16 3SU.
Registered in England No. 2795460.

Telephone: (01785) 220638 Facsimile: (01785) 214073 E-mail: enquiries@emclimited.co.uk
Registered Office, Unit 2, Brindley Close, Tollgate Industrial Estate, Stafford ST16 3SU.
Registered in England No. 2795460.

Declaration of Conformity

We, EMC Hycal Ltd., declare under our sole responsibility, that the Hycal Analyser, to which this declaration relates, is in accordance to the European EMC Directive 89/336/EEC, being compliant with the following:

EN 50081-2:1993 Electromagnetic Compatibility Generic Emission

Standard. Part 2: Industrial Environment

EN 50082-2:1995 Electromagnetic Compatibility Generic Immunity

Standard Part 2: Industrial Environment

We, also declare that same is in accordance with European Low Voltage Directive 73/23/EEC, being compliant with the following:

EN 61010-1:1993 including Amendment A2:1995 Safety Requirements for Electrical Equipment for measurement, control and laboratory use. Part 1: General Requirement.

The undersigned, hereby declares that the equipment designated herein conforms to the Directives and Standards shown above.

Mark Henson

EMC Hycal Limited

Director

Date: 15th July 2022

1 Introduction

The Hycal hydrogen measurement system provides rapid, accurate measurement of hydrogen dissolved in molten aluminium and its alloys. The system can be used to:

1. Perform spot measurements to check melt hydrogen levels prior to casting.
2. Continuously monitor dissolved hydrogen levels.
3. Control a metal treatment process in order to achieve a desired hydrogen concentration e.g. degassing.

The probe provides simultaneous measurement of dissolved hydrogen and temperature. Hydrogen sensing is achieved by an electrochemical hydrogen measurement cell located in the probe tip. Calibration is assured through individual calibration of each sensor in a precisely controlled hydrogen atmosphere, and through testing of each probe prior to shipment. Measurement precision throughout the lifetime of the probe is ensured through an integrated gas cylinder and purge system which prevents blockage and oxide build up. The gas system may also be used to perform in-situ calibration checking of the probe.

The Hycal analyser is a designed for maximum portability and ease of use on the shop floor. A folding mechanical arm allows easy positioning of the probe, and the analyser's internal rechargeable battery provides 8-14 hours of continuous use[1]. For extended measuring periods, external power is provided by a safe low-voltage DC power supply. Sophisticated On-Board Diagnostics (OBD) continuously monitor the condition of the probe and inform the operator if a problem is detected. An integrated heater maintains the probe at an elevated temperature during storage, preventing hydration and ensuring fast response time and optimum performance throughout its lifetime.

The analyser's numerous features are accessed via a touch-sensitive colour screen. The analyser offers secure and reliable data collection and storage (5 days of continuous readings) and is managed by a login system to prevent unauthorised access. Logged data may be transferred from the analyser to a PC computer by USB memory stick or over Ethernet, where it may be archived, viewed, printed, or exported to spreadsheet using the included PC software suite. The analyser's Ethernet connection offers remote control of the unit from a PC computer and easy integration onto a SCADA system via MODBUS TCP[2].

[1] Depending on screen brightness settings

[2] Other protocols are available with an additional Gateway option, please contact EMC.

1.1 Hycal versions

Hycal is available in 2 variants: a portable analyser 'Hycal' and a panel-mounted version, 'Hycal 1000'. Whilst the internals of each version are essentially identical, the general concept of the Hycal's design is to minimise size and weight. The Hycal 1000 series, with its more spacious, modular design is significantly larger and heavier yet lends itself more readily to the customization of its outputs such as on-demand actuation of the probe or for the control of degassing equipment and is therefore normally used as a fixed installation.

(i) Hycal

- Portable
- Battery or mains powered (via DC PSU)
- Integrated probe arm

(ii) Hycal 1000

- Fixed installation (industrial enclosure)
- Mains powered (AC voltages between 85 and 265 V RMS (47 to 63 Hz)).

1.2 Post shipment checking procedure

Please note that Hycal probes are not included with the Hycal analyser and must be ordered separately.

1.2.1 Hycal

The components supplied with a Hycal kit are listed below. Please use this list to check the shipment has arrived intact.

Item	**Quantity**
Packing case	1 off
Hycal analyser	1 off
DC power supply	1 off
DC power supply mains cable	1 off
DC power supply low voltage cable	1 off
Probe cable (1.2m)	1 off
Arm	1 off
Low pressure gas connector	1 off

1.2.2 Hycal 1000

Item	**Quantity**
Hycal 1000 analyser	1 off
Probe cable (3m)	1 off
RJ45 plug (IP68)	1 off
Low pressure gas connector	1 off

1.3 Working with Hycal

The Hycal is designed for production use where traceability is important. For this reason, dissolved hydrogen measurements may be associated with data critical to measurement accuracy (alloy setting and probe calibration) as well as other relevant information such as operator, melt code, and lot number. This data is recorded by the data logger and may be transferred to the PC software for further analysis and archiving (section 9). Measurement information may be entered at any time during general analyser operation, as detailed in section 3.7. However, in a production situation it may be necessary to ensure that the operator enters all data correctly. For this reason, the Hycal includes several "Guided" measurement modes, which guide the operator through the measurement process, and do not permit the measurement to proceed unless all required information has been entered or confirmed:

- Guided Measurement (section 5)
- Guided Degassing (section 6)
- Guided Calibration (section 7)

It is recommended that the engineer studies the fundamentals of Hycal operation presented in sections 2, 3, and 4, and that operators are then trained in using the "Guided" measurement modes mentioned above as required.

2 Analyser setup

2.1 Physical features

2.1.1 Hycal analyser

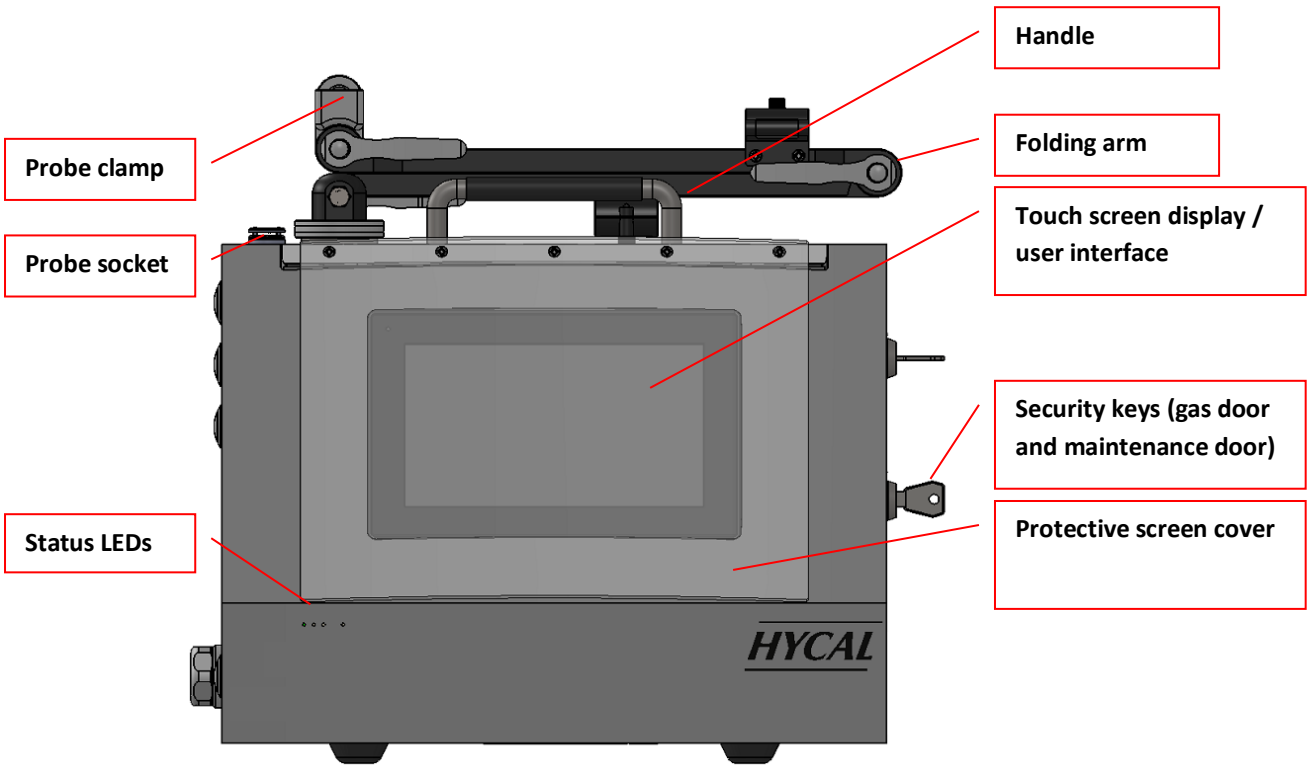


Figure 1: Hycal analyser front

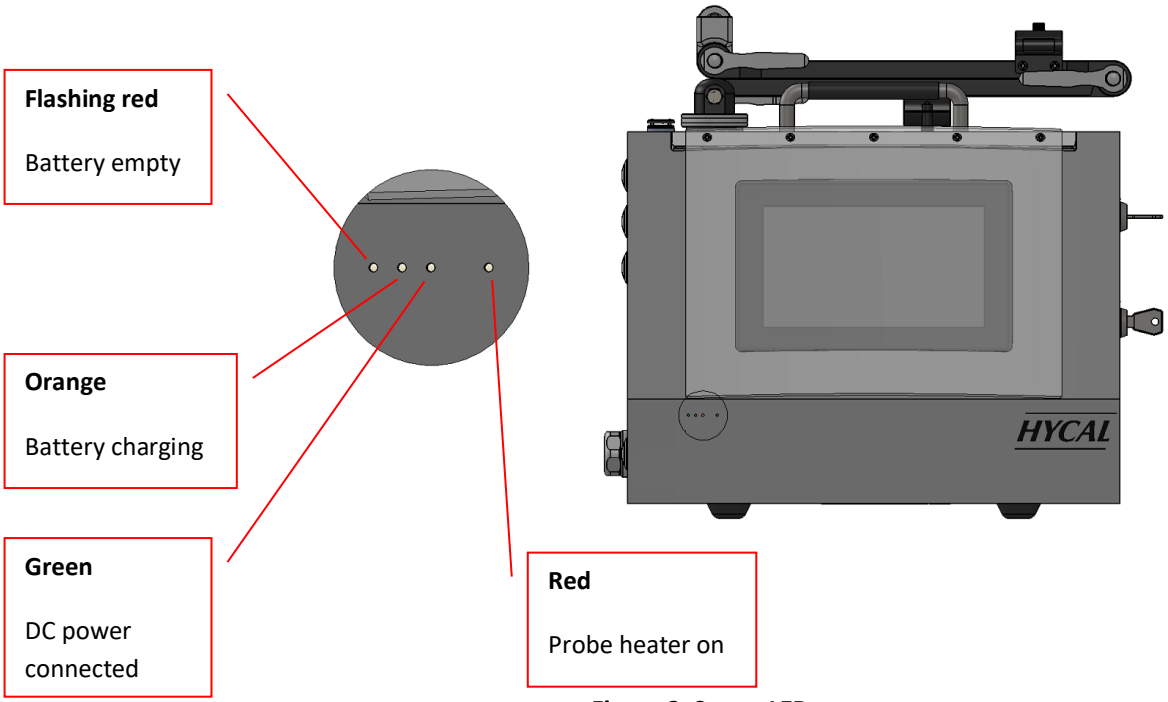


Figure 2: Status LEDs

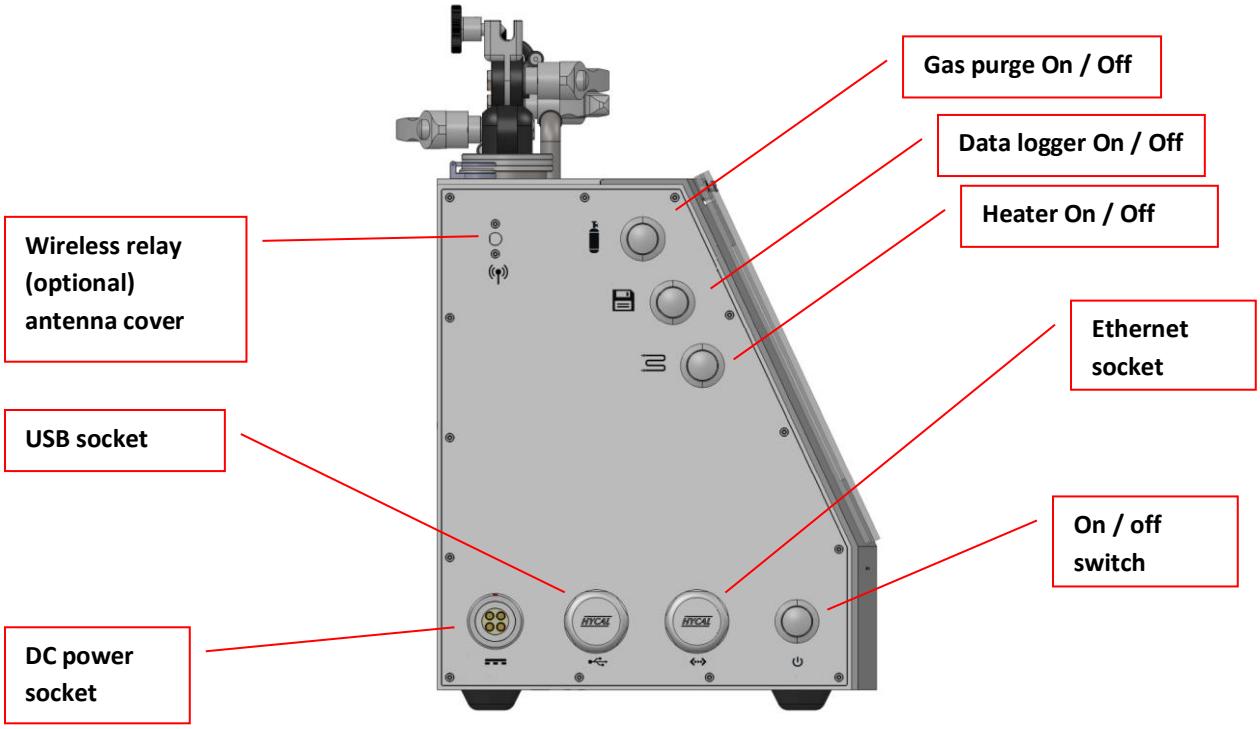


Figure 3: Hycal analyser electrical panel

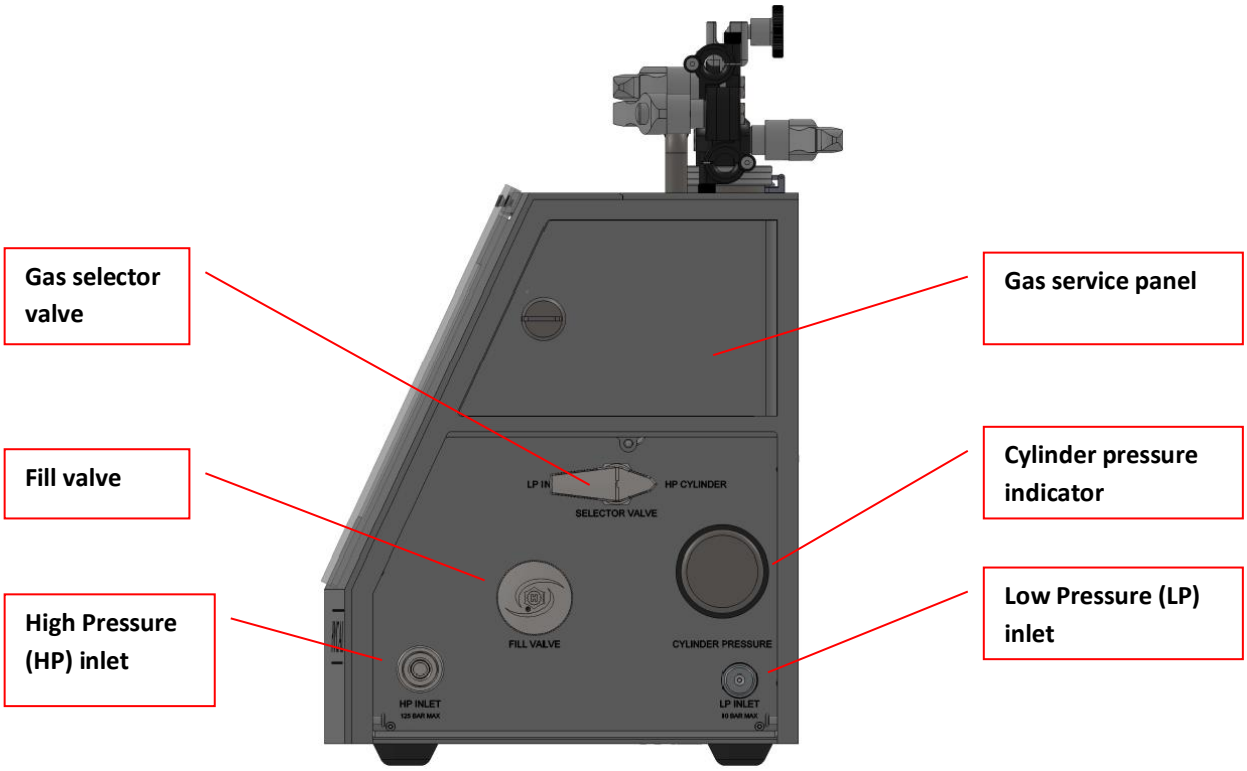


Figure 4: Gas panel

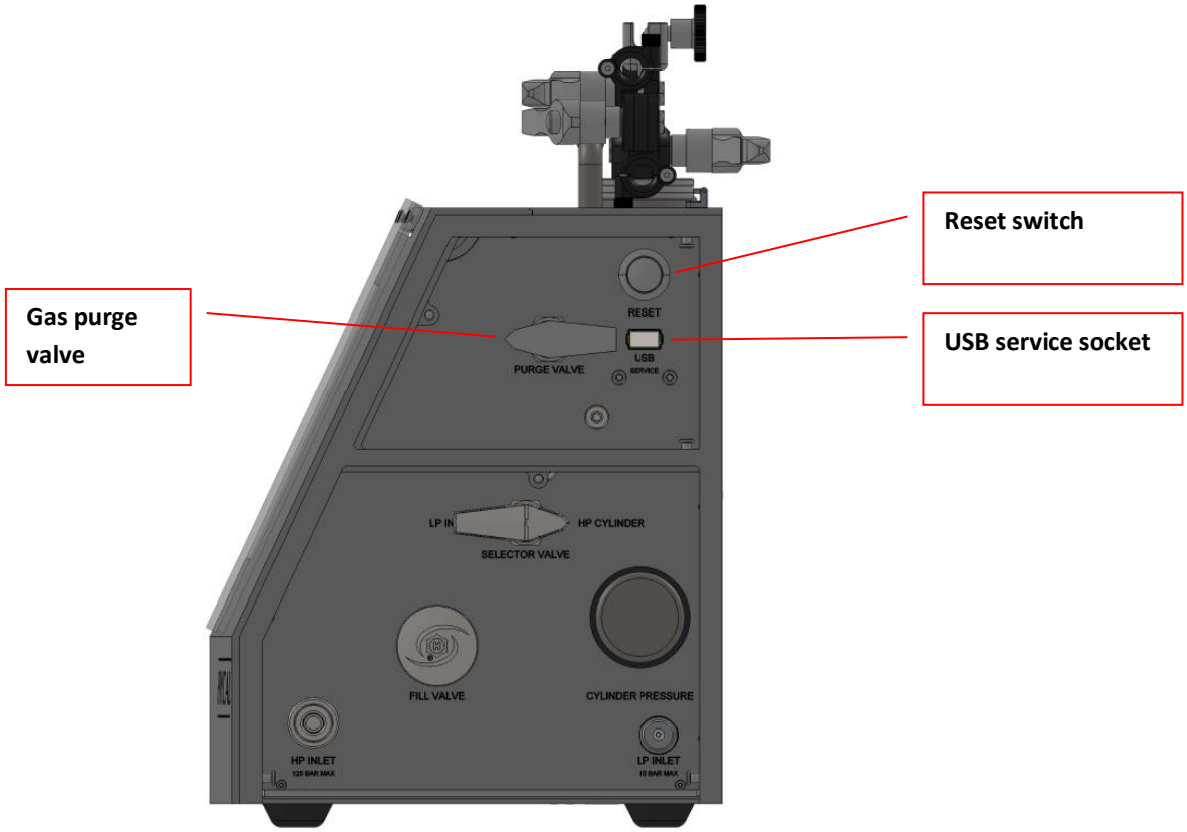


Figure 5: Service door opened

2.1.2 Hycal 1000 analyser

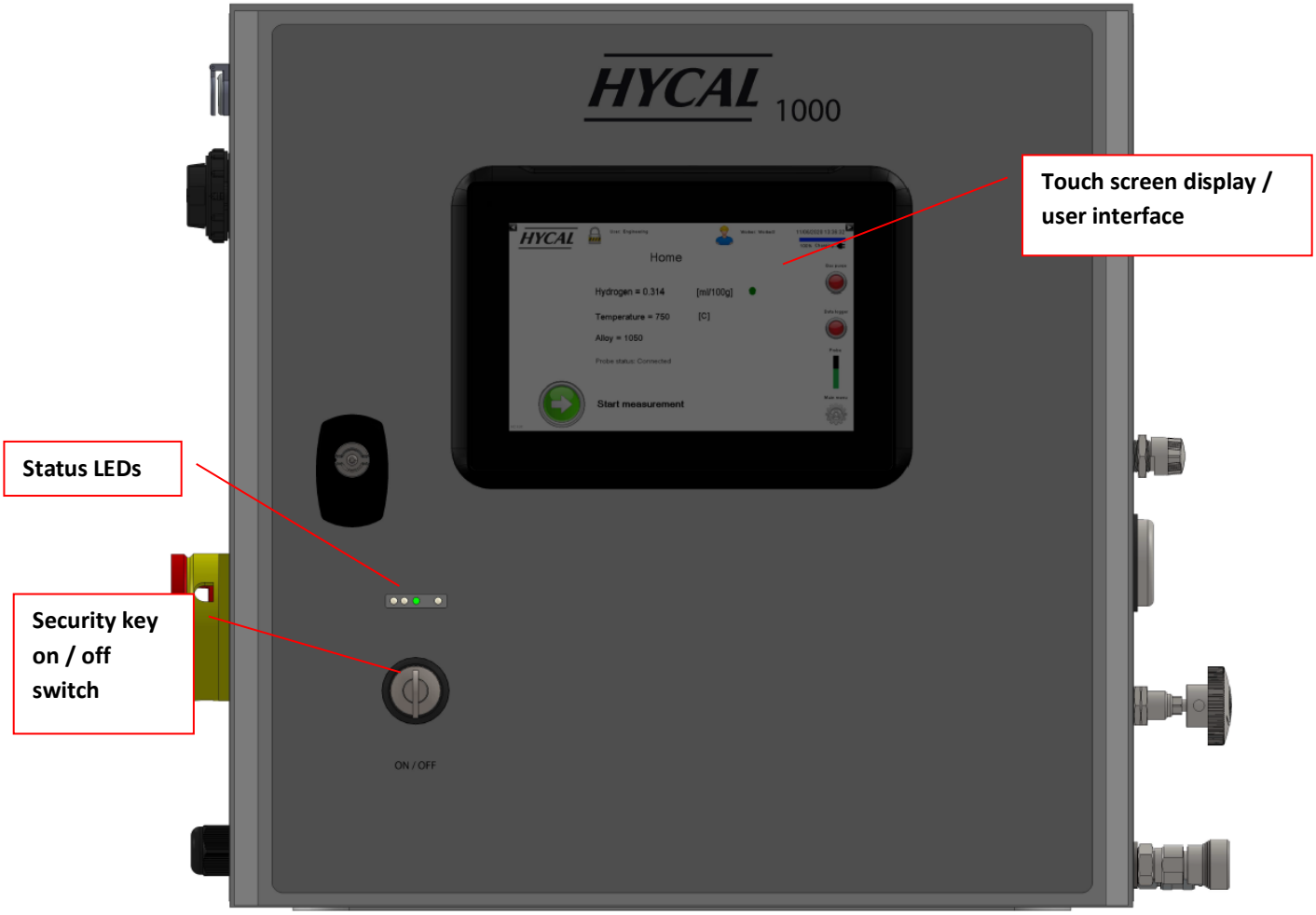


Figure 6: Hycal 1000 analyser

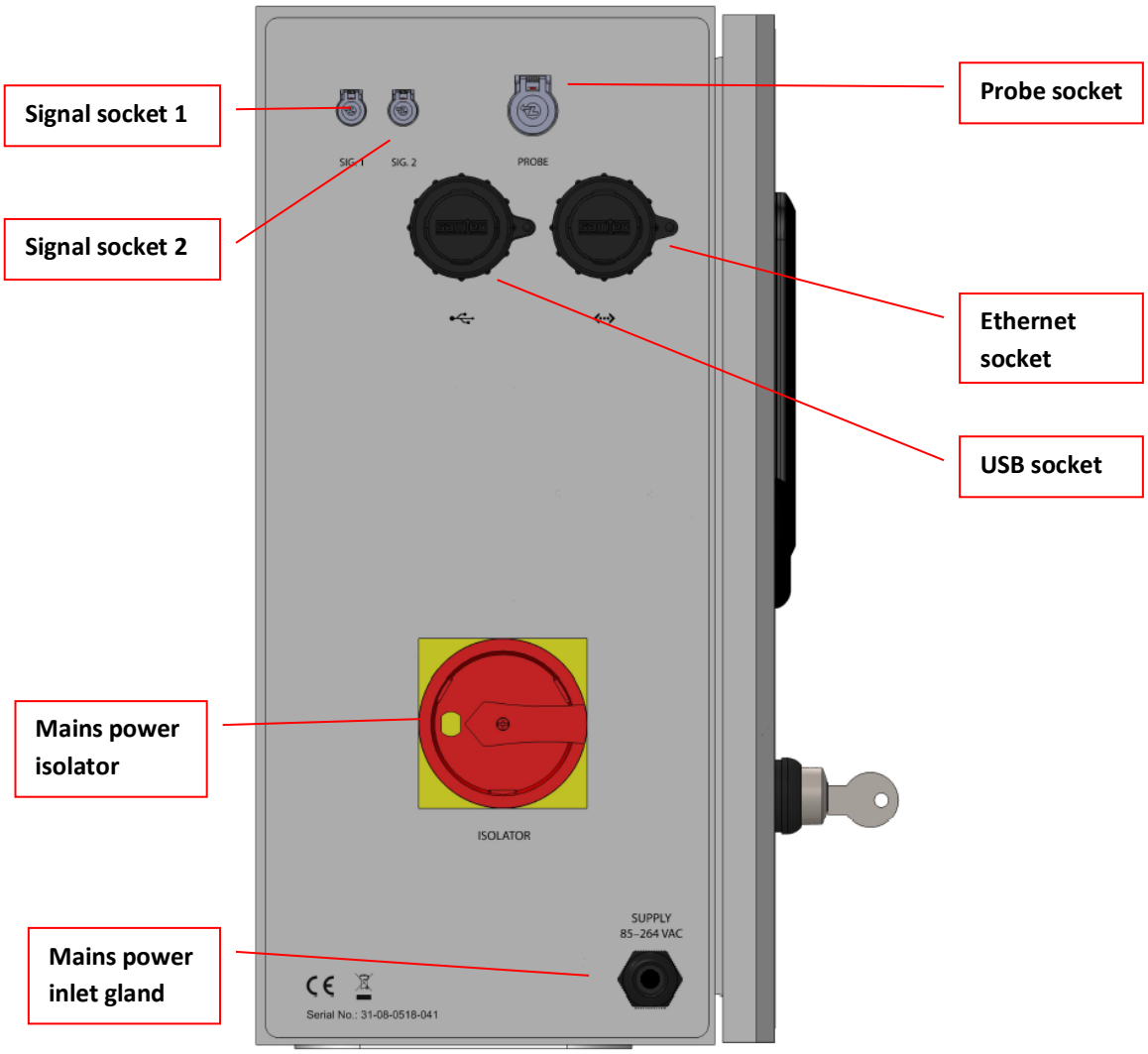


Figure 7: Hycal 1000 analyser electrical panel

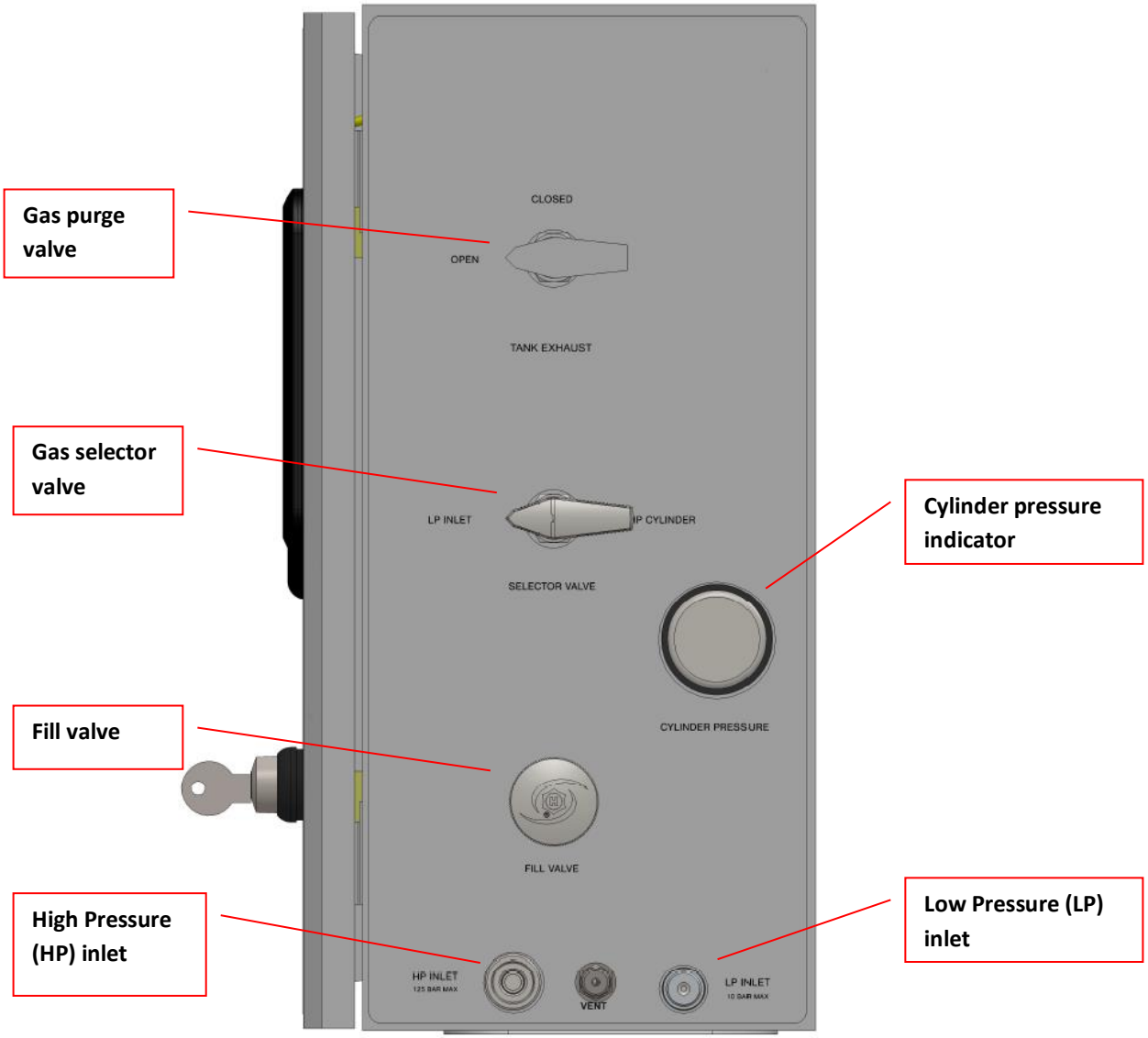
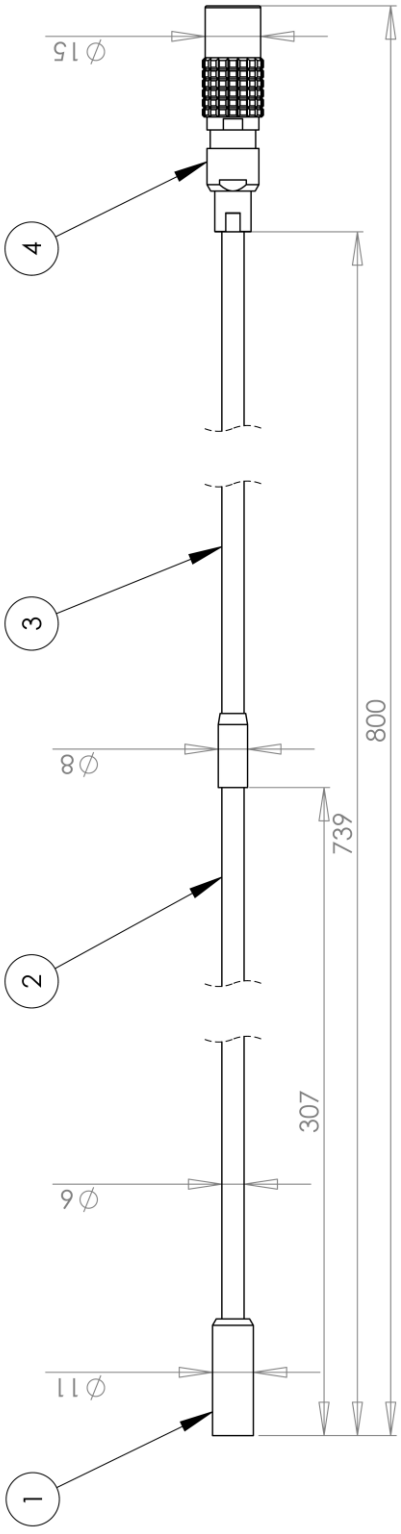


Figure 8: Hycal 1000 analyser gas panel

2.1.3 Hycal probe

2.1.3.1 Probe components



ITEM No.	DETAIL
1	Screw cap
2	Ceramic tube
3	Steel tube
4	Connector

Figure 9: Hycal probe (dimensions in mm)

2.1.3.2 Probe length

The overall length of the standard Hycal probe is 800mm; other lengths are available, see Table 1.

Ceramic length	Total length	Part number
300mm	500mm	HYC.PRB.003.005.256
300mm	800mm	HYC.PRB.003.008.255
300mm	1000mm	HYC.PRB.003.010.565
300mm	1200mm	HYC.PRB.003.012.347
300mm	1600mm	HYC.PRB.003.016.421
300mm	2000mm	HYC.PRB.003.020.566

Table 1: Hycal probe part numbers

2.2 Filling the gas cylinder

2.2.1 Prerequisites

The following are required to fill the Hycal analyser's internal cylinder:

1. Hycal refilling kit, part number HYC.AZR.UNI.ACC.004. This consists of the following:
    a. High pressure regulator
    b. 3-way valve
    c. Isolation valve
    d. High pressure hose terminated by a Quick Connect QC4 fitting
2. An industrial nitrogen gas cylinder (argon may also be used). Purity is not critical, but gas should be suitable for degassing of aluminium.

2.2.2 Procedure

The images in this section concern the Hycal analyser however the procedure for filling the Hycal 1000 cylinder is identical.

1. Connect regulator to gas bottle:

2. Turn white dial anti-clockwise to reduce outlet pressure setting to zero.

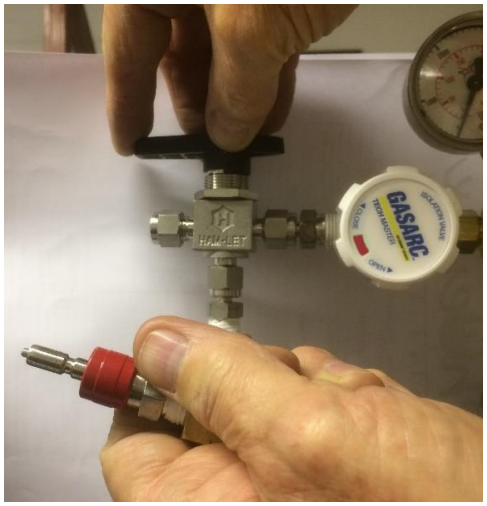
3. Open gas cylinder valve:

4. The inlet pressure should be 100+ bar and outlet should be zero on gauge:

5. Close isolation valve:

6. Turn white dial on regulator clockwise until the outlet pressure reaches 50 bar (725 psi)

7. Take QC4 quick-connect end and support whilst adjusting the 3-way valve:



8. Ensure 3-way valve is pointing towards the regulator (this will fill the pipe up with nitrogen):

9. Open the isolation valve (rotate anticlockwise):

10. Then turn three-way valve away from the regulator (which will vent the gas inside the pipe):

11. Repeat step 9 and 10 (3 times) to completely displace trapped air from the system.
12. Finally, leave the 3-way valve pointing away from the regulator.
13. Insert the quick-connect fitting into the HP socket into the Hycal (push firmly until the connector clicks into position such that it cannot come back out again):

14. Turn the 3-way valve to point to the regulator, ensuring that the isolation valve is still in the open position (showing green):

15. Open the ‘HP fill valve’ on the Hycal by turning anti-clockwise:

16. Turn white dial on regulator clockwise to increase the pressure:

17. Increase pressure until gauge on the Hycal reaches 100-110 bar:

18. Close HP Fill Valve (turn clockwise) on Hycal:

19. Close the cylinder valve:

20. **WARNING – AT THIS STAGE, THE PIPE IS STILL PRESSURISED TO 100+ BAR AND MUST BE DE-PRESSURISED BEFORE REMOVAL!**

21. Turn white dial anti-clockwise fully to reduce outlet pressure to zero on regulator:

22. Slowly turn 3-way valve away from regulator to vent the pressure in the pipe to atmosphere:

23. Turn 3-way valve towards regulator to allow the excess pressure to enter the pipe again:

24. IMPORTANT: REPEAT STEP 23-24 SEVERAL TIMES UNTIL NO GAS IS VENTED AT STEP 23 - THIS ENSURES THE PIPE IS SAFE TO REMOVE FROM ANALYSER.

25. Whilst supporting the pipe in one hand, pull on the quick connect socket to withdraw the outer sleeve – which allows the connector to be removed:

26. Remove fill-pipe:

27. The Hycal can now be used, and the regulator may be disconnected from the gas cylinder:

2.3 Connecting an external gas line

Prerequisites:

(i) An external gas supply of nitrogen or a calibration gas mixture of hydrogen in an inert carrier gas (nitrogen or argon), at a pressure of 3 - 10 bar.

(ii) A 6mm plastic gas delivery hose.

(iii) The low-pressure gas connector included with the Hycal.

Follow the procedure below to connect an external gas supply to the Hycal analyser:

1. Fit the low-pressure gas connector to the 6mm plastic hose.
2. Push the 6mm delivery hose into the Hycal's LP INLET.
3. Set the Hycal's SELECTOR VALVE to LP INLET.

2.4 Gas service panel

The gas service panel may be opened using the key providing access to the following (Figure 5):

1. The USB service socket. This is used to upload firmware updates to the Hycal's data acquisition unit, and to load custom alloy files.
2. The purge valve. This may be used to manually empty the internal gas cylinder.
3. Reset switch. This is used to reset the Hycal's data acquisition unit (if advised to do so by EMC during service operations).

2.5 Emptying the gas cylinder

The internal gas cylinder should be emptied prior to transit.

1. Open the gas service panel
2. Open the purge valve (Figure 5)
3. Wait until the cylinder pressure indicator reads zero (Figure 4)
4. Close the purge valve
5. Close the gas service panel

3 Analyser operation

3.1 Power requirements

The Hycal analyser can operate from its internal battery or from a mains voltage source using the included DC power supply unit. The battery provides 8 - 14 hours of continuous running time, depending on screen brightness settings. The DC power supply unit is suitable for use with all AC voltages between 85 and 265 V RMS (47 to 63 Hz). Voltage selection is automatic. The supplied DC power cable mates with the power socket on the side panel of the analyser (see Figure 3).

3.1.1 Charging the battery

To fully charge the Hycal's battery, proceed as follows:

1. Ensure that the analyser is at 0 - 25C (see Table 2).
2. Plug the DC power supply into the mains supply.
3. Connect the DC power supply low voltage cable from the power supply to the Hycal's DC power socket (see Figure 3). The green status LED on the Hycal front panel will illuminate, to indicate that DC power is connected.
4. If the battery is not already fully charged, then charging will start and the orange status LED will illuminate.
5. When charging is complete the orange LED will turn off.

A battery charge indicator is shown in the top right-hand corner of the analyser screen. Analyser charging depends on temperature as shown in Table 2:

Temperature	Battery charging
0 - 25°C	Battery will charge normally.
25 - 45°C	Battery will charge but will pause occasionally to prevent overheating.
45 - 70°C	Battery will not charge. Analyser may still be used but if charging is required analyser must be moved to a cooler location.

Table 2: Hycal analyser operating temperature

3.2 Starting the analyser

Press the on / off switch on the side of the unit (see Figure 3). The analyser's status LEDs (

Figure 2) will flash in sequence to indicate that the unit is starting up. After approximately 1 minute the analyser's "Home" screen will appear as shown on Figure 10.

3.3 Home screen

The "Home" screen displays the hydrogen and temperature readings, currently selected alloy and status information about the probe. The top right of the screen displays the time, date, and battery status indicator.

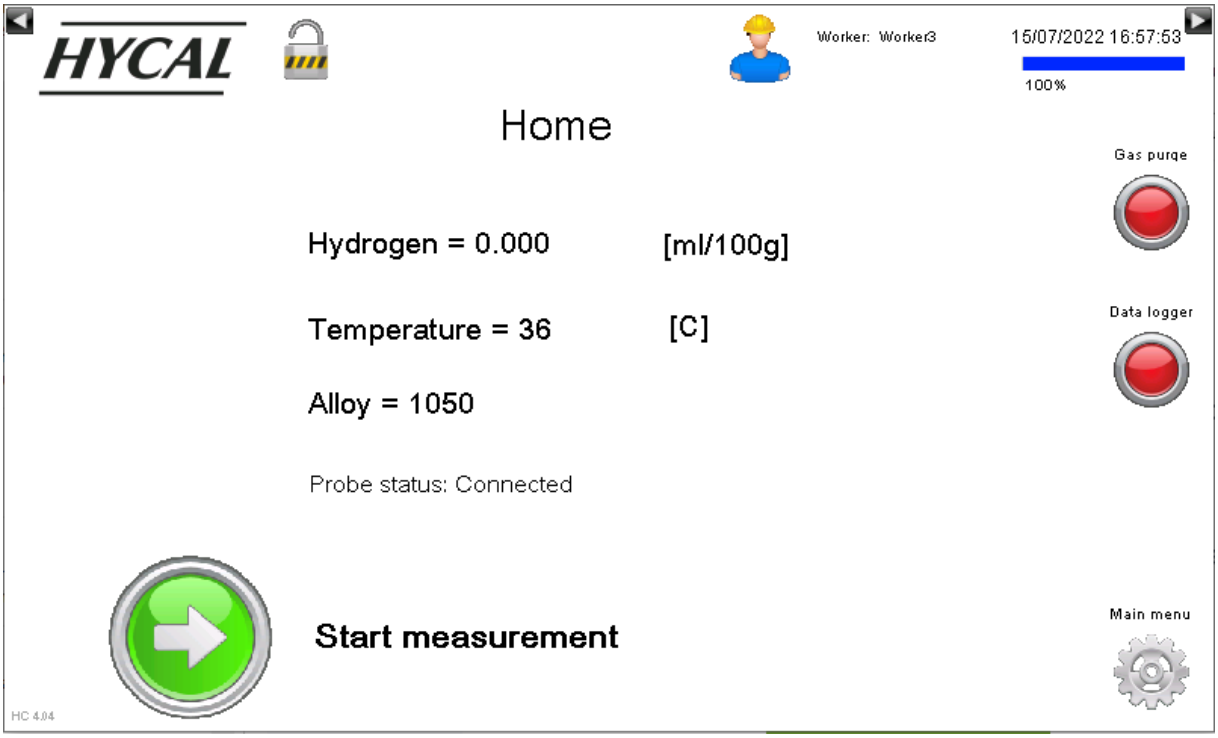


Figure 10: Home screen

3.4 Security

3.4.1 Logging in

The open padlock symbol at the top left of the screen indicates that no users are currently logged in. There are 5 security levels:

Security level	Default password	Detail
Not logged in	N/A	Cannot enter probe calibration values. Cannot start a Guided Measurement. Cannot view / change analyser settings.
Operator	010	Cannot enter probe calibration values. Can start a Guided Measurement. Cannot view / change analyser settings.
Manager	001	Can enter probe calibration values. Cannot start a Guided Measurement. Cannot view / change analyser settings.
Engineering	100	Can enter probe calibration values. Can start a Guided Measurement. Can view / change analyser settings. Additional diagnostic information is shown on some screens.
Service EMC	N/A	Used for internal procedures such as instrument calibration (EMC use only).

Table 3: Hycal analyser security levels & default passwords

- To log in, first lift the protective screen cover and press the padlock symbol. The "Login" screen will appear (Figure 11).
- Press the down arrow next to "User", then select the required access level e.g. "Engineering"
- Press inside the "Password" text box. An on-screen keyboard will appear. Enter the password for the selected user. If a mistake is made, characters can be deleted using the left arrow key near the top right of the on-screen keyboard.
- A message will appear confirming the login, press "OK"
- The padlock at the top of the screen will changed to a locked state indicating that a user is logged in

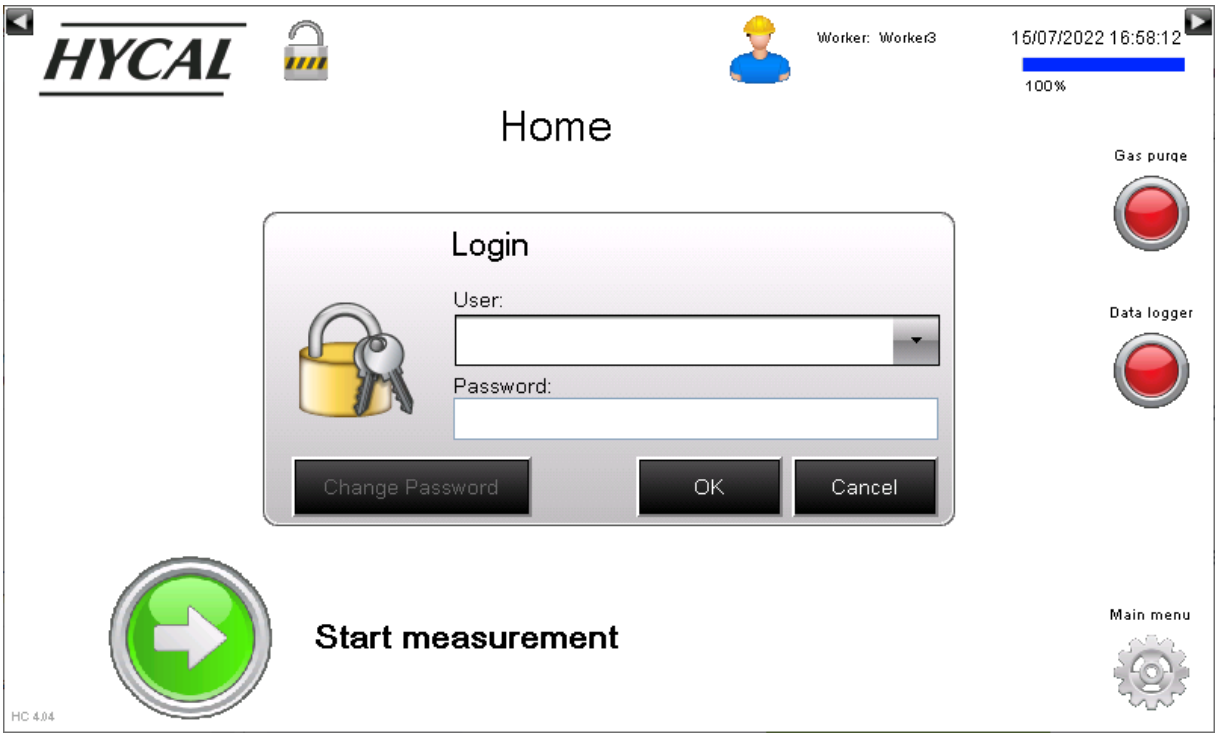


Figure 11: Login screen

3.4.2 Logging out

To log out, press the padlock icon at the top of the screen. A message will appear confirming that the user has logged out, press "OK" to acknowledge.

3.4.3 Changing the password

The default passwords may be changed by the user for increased security.

- First log out then press the padlock symbol to activate the "Login" screen (Figure 11).
- Press the down arrow next to "User", then select the required access level
- Press the "Change Password" button.
- Press the text field below "Old Password" and use the on-screen keyboard to enter the existing password.
- Proceed in a similar manner to enter the new password into the "New Password" and "Confirm Password" fields then press "OK". Any alphanumeric characters may be used, and the passwords are case sensitive.
- A message will appear confirming the change, press "OK" to acknowledge.

3.5 Main menu & navigation

The "Main menu" provides access to many of the Hycal analyser's features. It may be shown by pressing the icon in the bottom right corner of the screen. To hide the main menu, either press "Close" or press "Main menu" again.

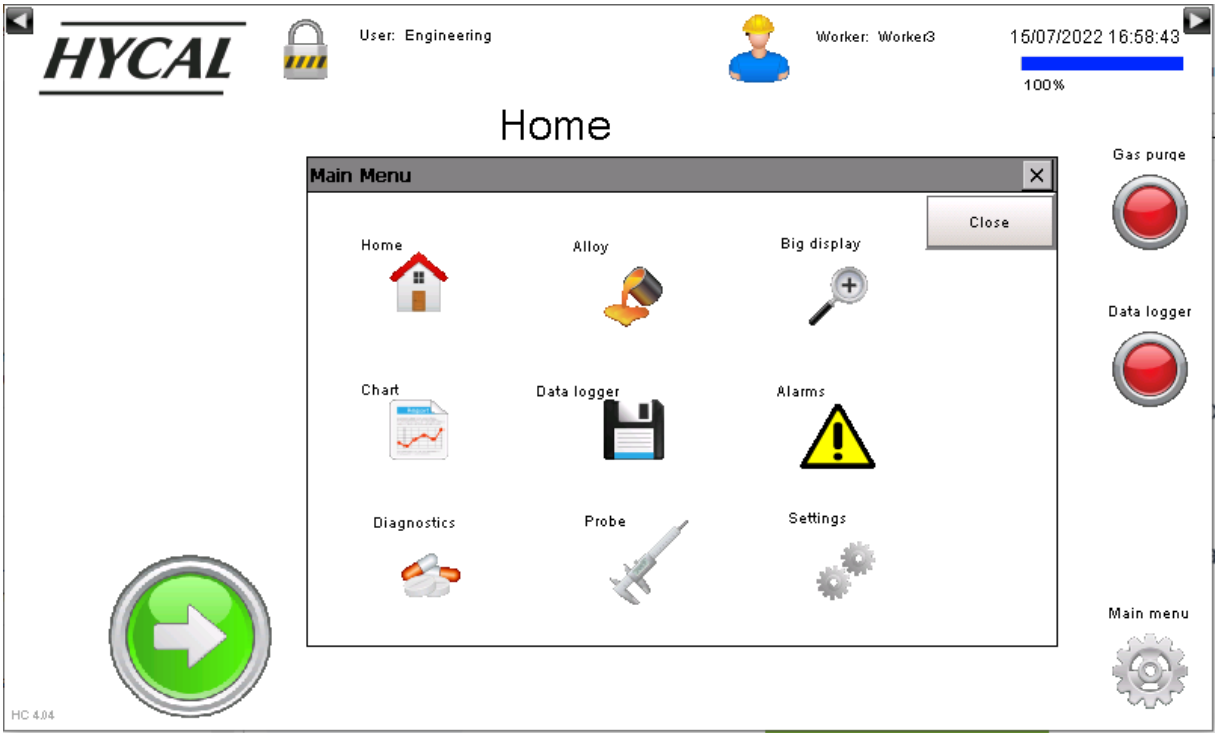


Figure 12: Main menu

3.6 Instrument settings

To access the "Settings" menu, the user must first log in by following the instructions in section 3.3. After logging in, press the “Main menu” button in the bottom right hand corner of the screen, then press "Settings".

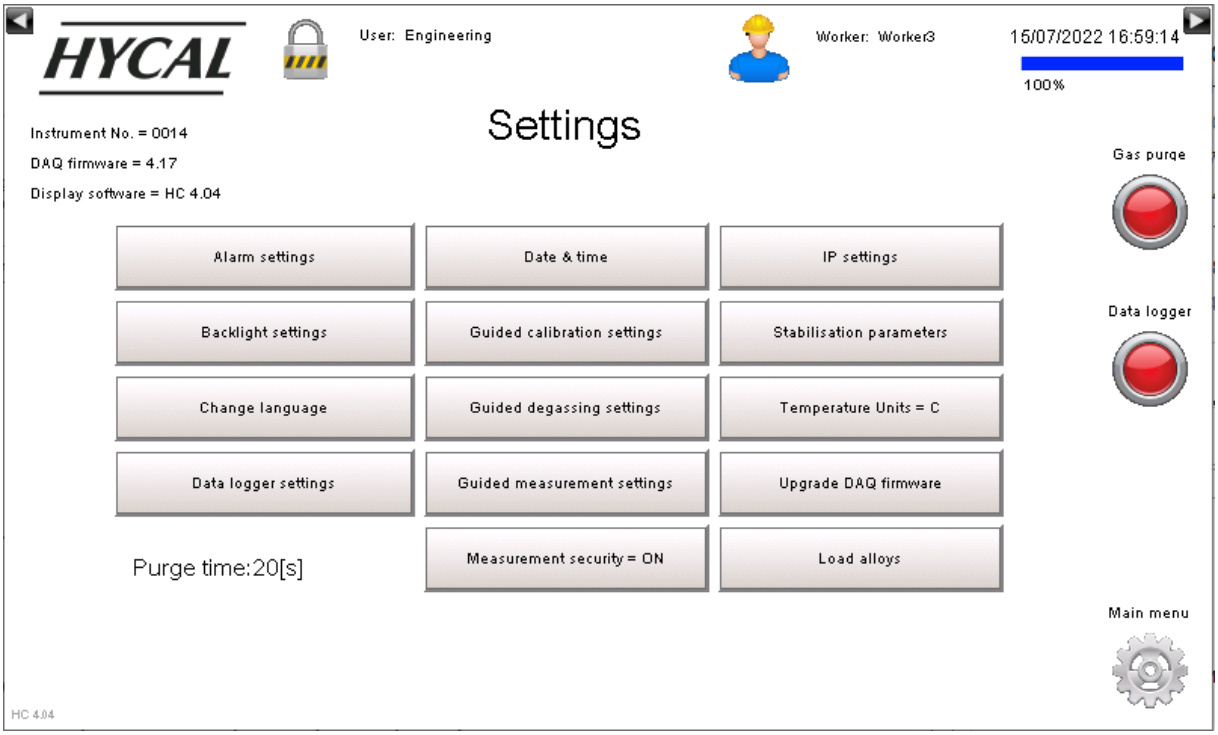


Figure 13: Settings screen

3.6.1 Alarm settings

Allows viewing / changing of the Hycal's hydrogen alarm facility, and parameters for RDU control (see section 6):

- Alarm on or off
- Set "Bounce threshold" (see section 6)
- Set "Dwell time" (see section 6)

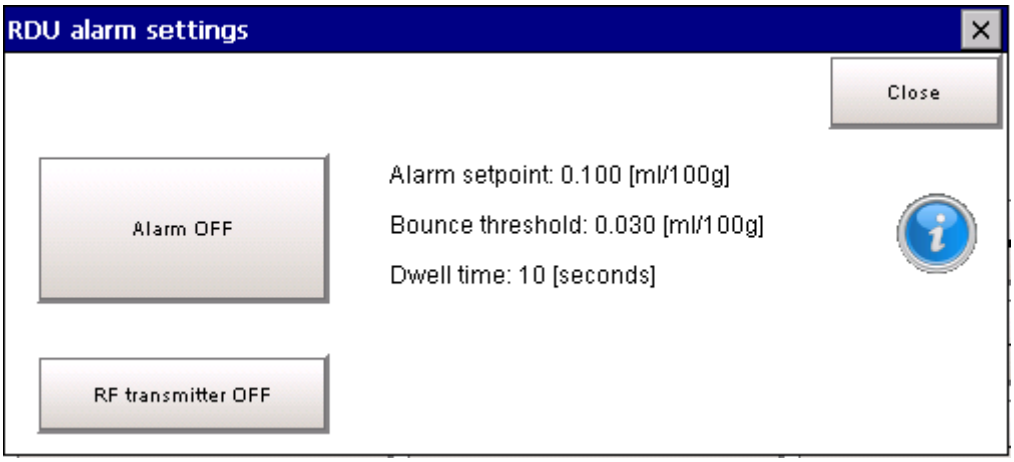


Figure 14: RDU alarm settings

3.6.2 Date and time

The date and time are displayed in the top right-hand corner of the analyser screen. To change, select "Date & Time" from the "Settings" menu and adjust using the on-screen controls (Figure 15).

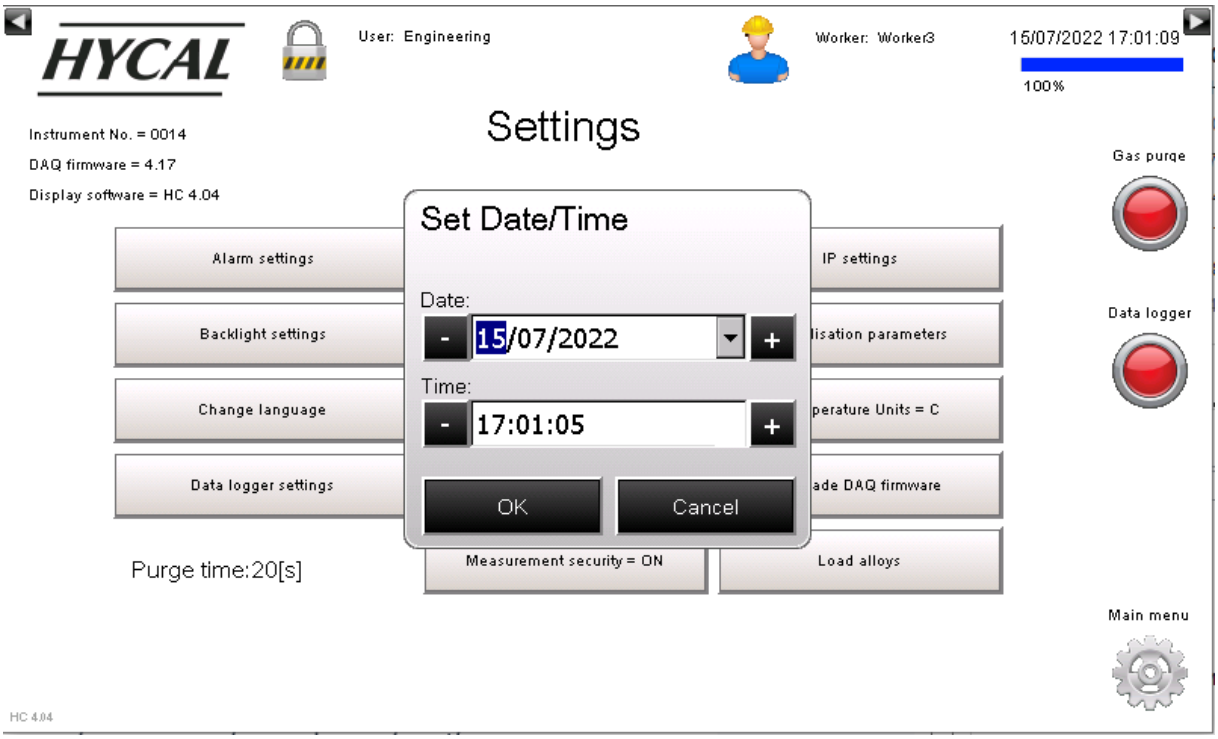


Figure 15: Setting date & time

3.6.3 IP settings

By default, the analyser is set to obtain an IP address automatically from a DHCP server. To change the IP settings, proceed as follows:

- From the "Settings" menu press “IP setting "

- Press "Specify an IP address" then enter the desired IP address, subnet mask, and default gateway using the on-screen keypad. Pres s "OK" to confirm
- Switch the analyser off then back on

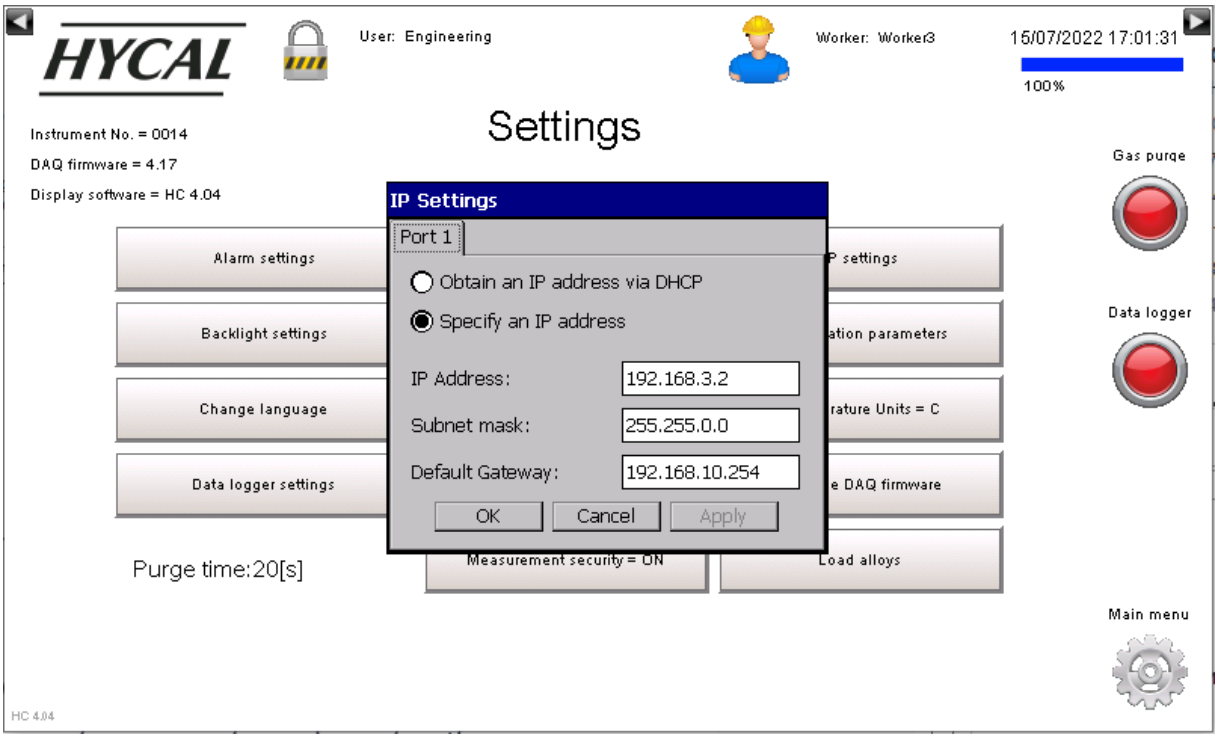


Figure 16: IP settings

3.6.4 Backlight settings

The analyser can save battery life by dimming the display's backlight and / or switching the display off after predefined periods of inactivity. By default, the analyser display is set as follows:

- 100% brightness when in use
- Backlight dims if the screen is not touched for 120 seconds
- Screen switched off if it is not touched for 5 minutes

These settings can be changed as follows:

- From the "Settings" menu press “Backlight settings"
- Adjust the slider to set the screen brightness when analyser is in use
- To disable the screen dimmer facility, press on the green tick next to "Screen dimmer". The green tick will become a red cross indicating that the screen dimmer has been turned off

- To adjust the screen dimmer timer, press on the number to the right of the text "Dimmer timer =" to activate an on-screen keypad. Enter the desired screen dimming time then press the "Return" key in the bottom right of the keypad to enter the change.
- Proceed in similar manner to disable or adjust the screen switch off facility if desired

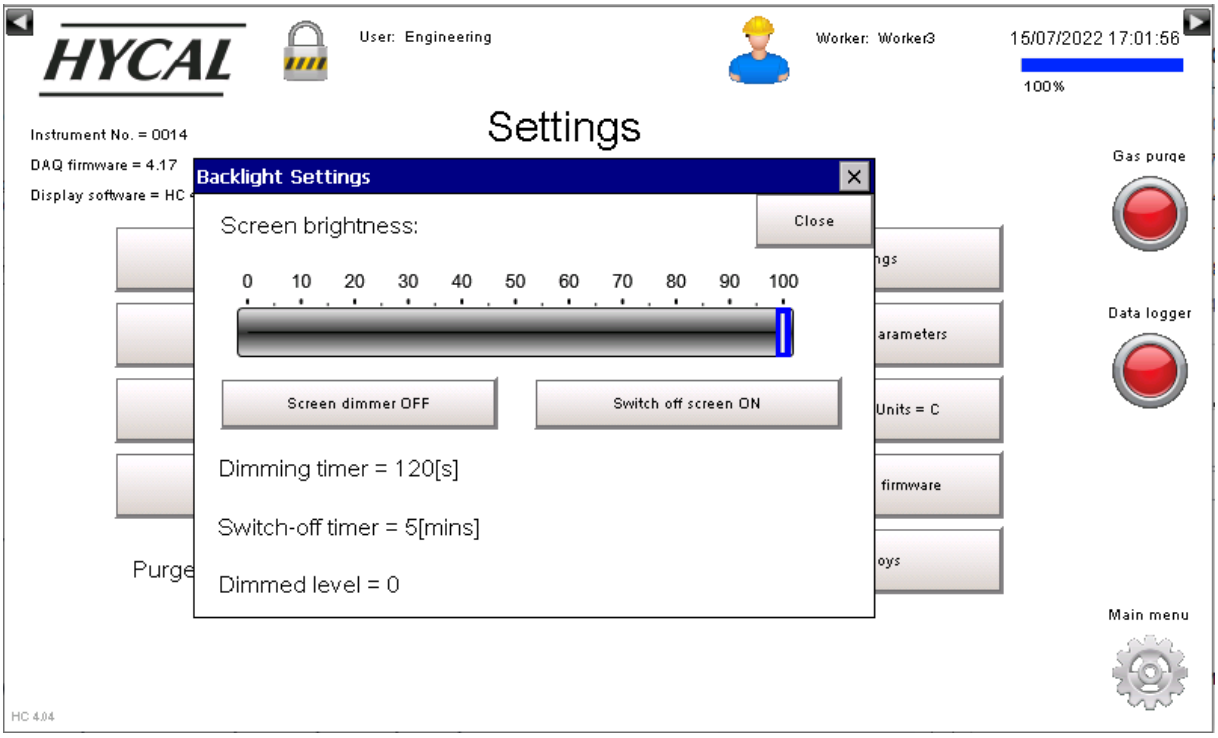


Figure 17: Backlight settings

3.6.5 Guided Calibration settings

Settings concerning Guided Calibration, see section 7.

3.6.6 Stabilisation parameter settings

When immersing the Hycal probe into molten aluminium, the probe must reach temperature and hydrogen equilibrium before it can measure accurately. The Hycal analyser includes a stabilisation algorithm to detect if measurement conditions have stabilised. When a stable reading is detected, a circular green marker appears next to the displayed hydrogen value to indicate stability. Detection of stability is determined by 3 parameters; change in hydrogen, change in temperature and number of readings, see Table 4 and Figure 18.

Parameter	Minimum	Maximum	Default
Change in hydrogen	0.001	0.500	0.005
Change in temperature	0.5	6	5
Number of readings	2	30	30

Table 4: Stabilisation parameter defaults

A reading is deemed to be stable if, over the number of readings specified by the user:

(i) Difference between maximum and minimum temperature is less than or equal to stabilisation parameter X [C]

AND

(ii) Difference between maximum and minimum hydrogen is less than or equal to stabilisation parameter Y [ml/100g]

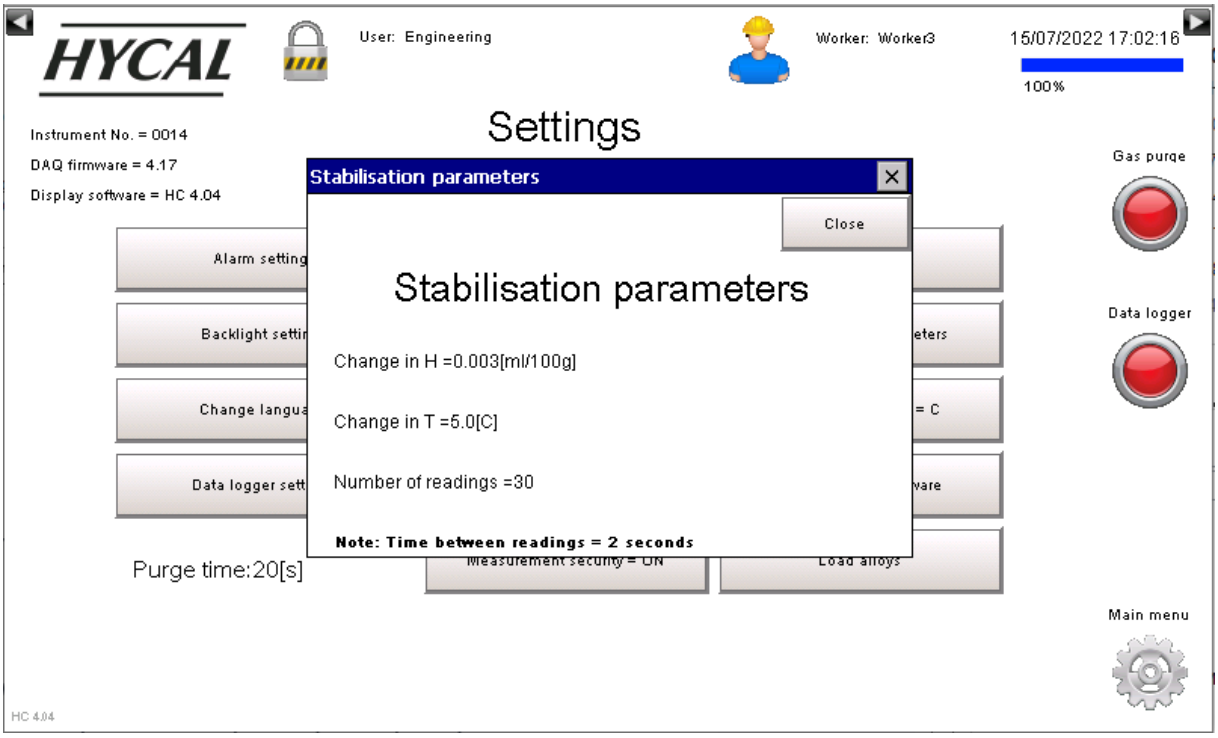


Figure 18: Stabilisation parameters

The time between readings is 2 seconds therefore if "Number of readings" is set to 30 this corresponds to 1 minute of data.

3.6.7 Change language

The following languages are supported:

- English
- French
- German
- Japanese

3.6.8 Guided degassing settings

Settings concerning Guided Calibration, see section 6.4.

3.6.9 Temperature units

Pressing the Temperature Units buttons switches between Celsius and Fahrenheit.

3.6.10 Data logger settings

The data logger settings screen allows the data logger chart scale to be changed. It provides a read out of the data logger memory used, both as a percentage and as the remaining log time available in days, hours and minutes. The data logger may be deleted by pressing the "Delete data logger" button and selecting "Yes" when prompted for confirmation.

Note: Deleting the data logger can take up to 2 minutes if the memory is full.

The data logger settings may also be accessed directly from the "Data logger" screen. This will allow the operator to change the chart scale, however it is not possible to delete the data logger unless the user is logged in as Engineering.

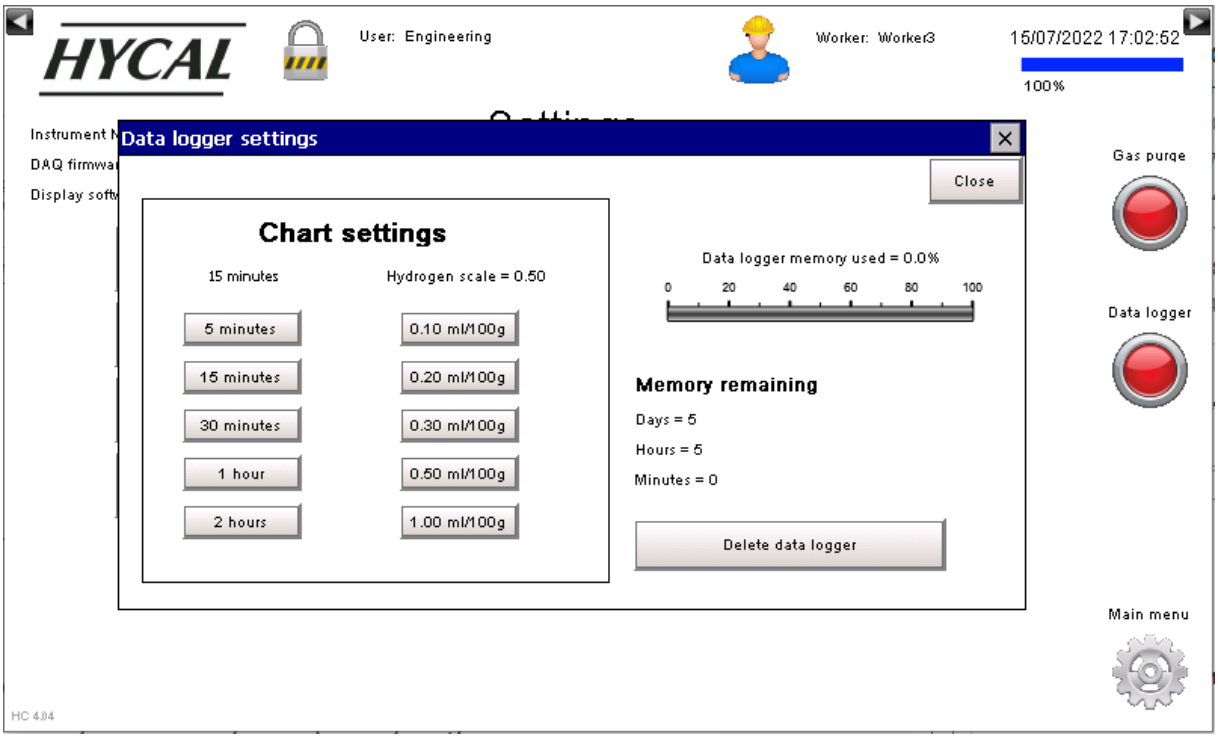


Figure 19: Data logger settings

3.6.11 Guided Measurement settings

Settings concerning Guided Measurement, see section 5.2.

3.6.12 Measurement security

If measurement security is turned on then the user cannot start a Guided Measurement unless they are logged in as Operator or Engineering (set to ON by default).

3.6.13 Upgrade DAQ firmware

Allows upgrade of the Hycal's data acquisition unit firmware by USB memory stick. See section 8.2.2.

3.6.14 Load alloys

A new alloy list may be loaded onto the Hycal as follows:

1. EMC personnel will provide an alloy file "alloydat.all" by email or otherwise. Copy this file onto the root directory of a USB memory stick
2. Open the gas service panel (Figure 5).
3. Insert the USB memory stick into the port labelled "USB SERVICE".
4. Log in as Engineering, navigate to the "Settings" then press "Load alloys".
5. Press the "Press to load alloy file" button.
6. The Hycal analyser will copy the alloy file and then display the message requesting removal if the USB memory stick. Remove the USB stick then press “Close”
7. Wait for the alloy list to synchronise inside the Hycal (takes approx.. 20 seconds)
8. The new alloys have now been loaded and may be viewed from Main menu -> Alloy

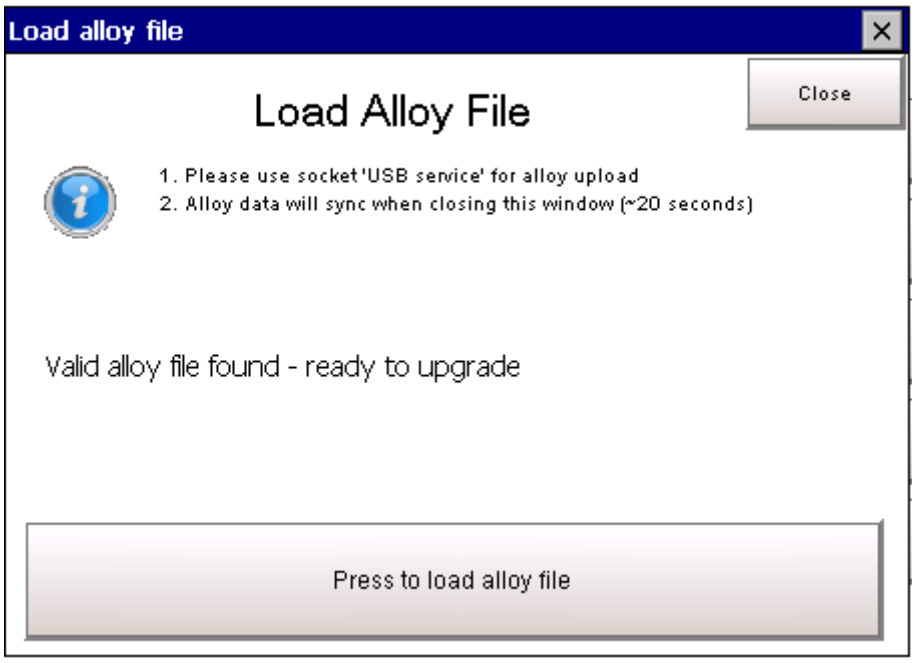


Figure 20: Load alloys screen

3.6.15 Purge time

Press the number next to "Purge time:" to adjust the duration of the Hycal analyser's gas purge cycle. Use the on-screen keypad to enter the desired purge time (in seconds) then press the "Return" key in the bottom right of the keypad to enter the change.

3.7 Measurement settings

The Hycal analyser must be programmed with the correct alloy calibration constants and probe calibration constants to measure accurately. Additional information concerning the measurement may also be set, which is recorded by the data logger for measurement traceability:

- Worker
- Batch number
- Melt code

3.7.1 Alloy calibration

Two alloy calibration values are required (C and D) which depend on the chemistry of the melt. The Hycal analyser contains a library with the calibration constants of up to 100 alloys, divided into 5 groups of 20 alloys. To change the alloy, either press the alloy text or press "Main menu" then "Alloy". Select the desired alloy group then the desired alloy. Group buttons become orange and alloy buttons green to indicate selection. It is possible to make the pre-programmed groups and alloys specific to the customer's requirement.

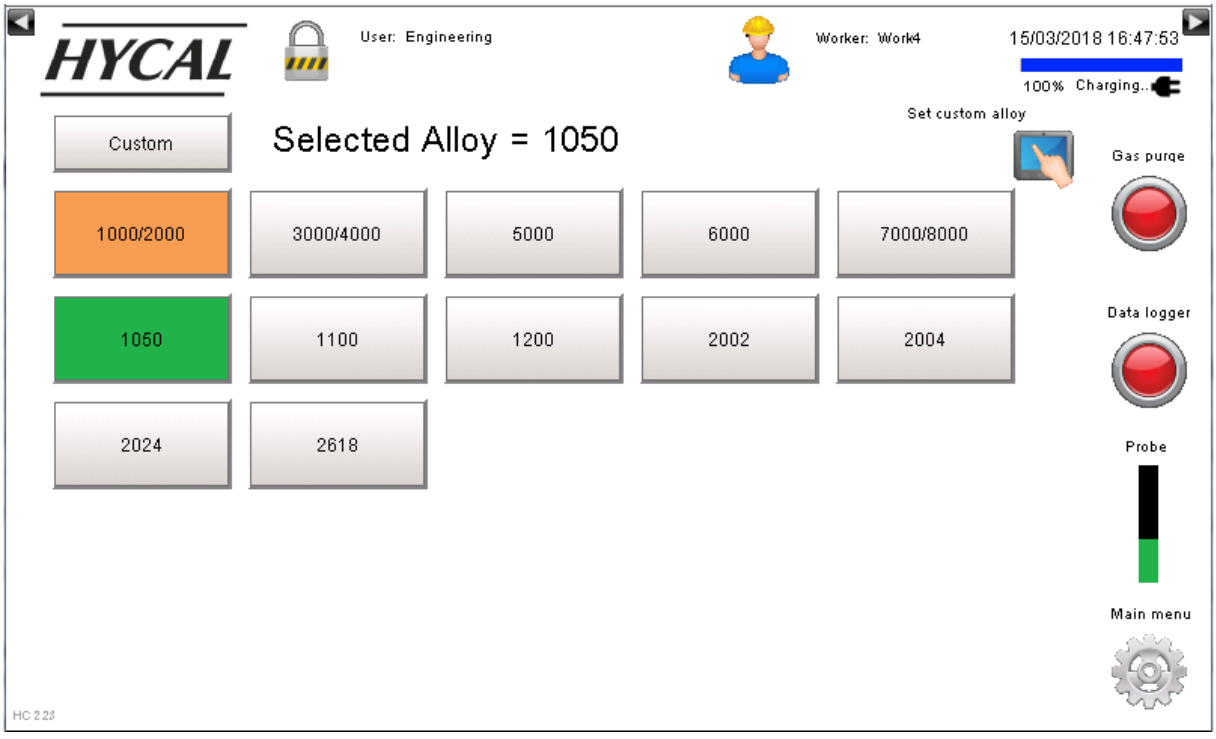


Figure 21: Alloy screen

3.7.1.1 Custom alloy

In addition to the pre-set alloys there is a "Custom" alloy setting which may be programmed manually. To program, log in as Engineering, to make the "Set custom alloy" icon visible (see Figure 21). On pressing the icon, the user is prompted to enter the C and D calibration values for the Custom alloy. When the values have been entered press Custom on the Alloy screen to select the custom alloy.

3.7.2 Probe calibration

The hydrogen measurement cell inside each Hycal probe is individually calibrated in a furnace containing a known partial pressure of hydrogen over a range of temperature. This procedure produces 4 calibration constants which are supplied with each Hycal probe:

(i) A and B. These are calibration constants which ensure accuracy of the hydrogen reading.

(ii) Z700 and Z750. These are diagnostic constants used to ascertain proper operation of the probe, they have no influence on hydrogen reading.

These calibration constants should be entered into the analyser:

1. Log in by following the instructions in section 3.4.1
2. Press the "Probe" icon at the right of the screen[3] or select "Main menu" then "Probe"
3. Press "Probe number" then enter the correct probe number. Repeat for A, B, Z700 and Z750.

Note: User must be logged in as Engineering to change the probe number and calibration values

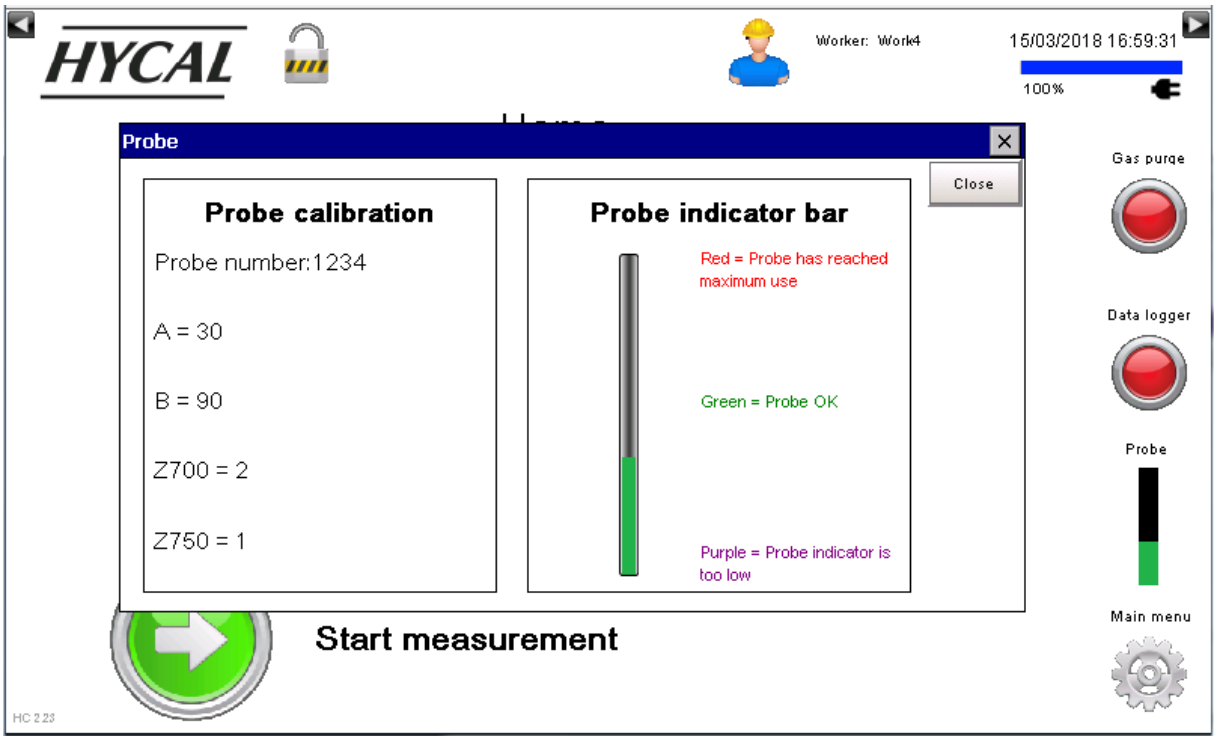


Figure 22: Probe screen

[3] "Probe" icon is only visible when temperature >600C

3.7.3 Worker

To specify which operator or "Worker" is conducting the hydrogen measurements, press "Worker" at the top of the screen to show the "Worker" selection screen (Figure 23) then select the worker. This is recorded by the data logger when the logger is on.

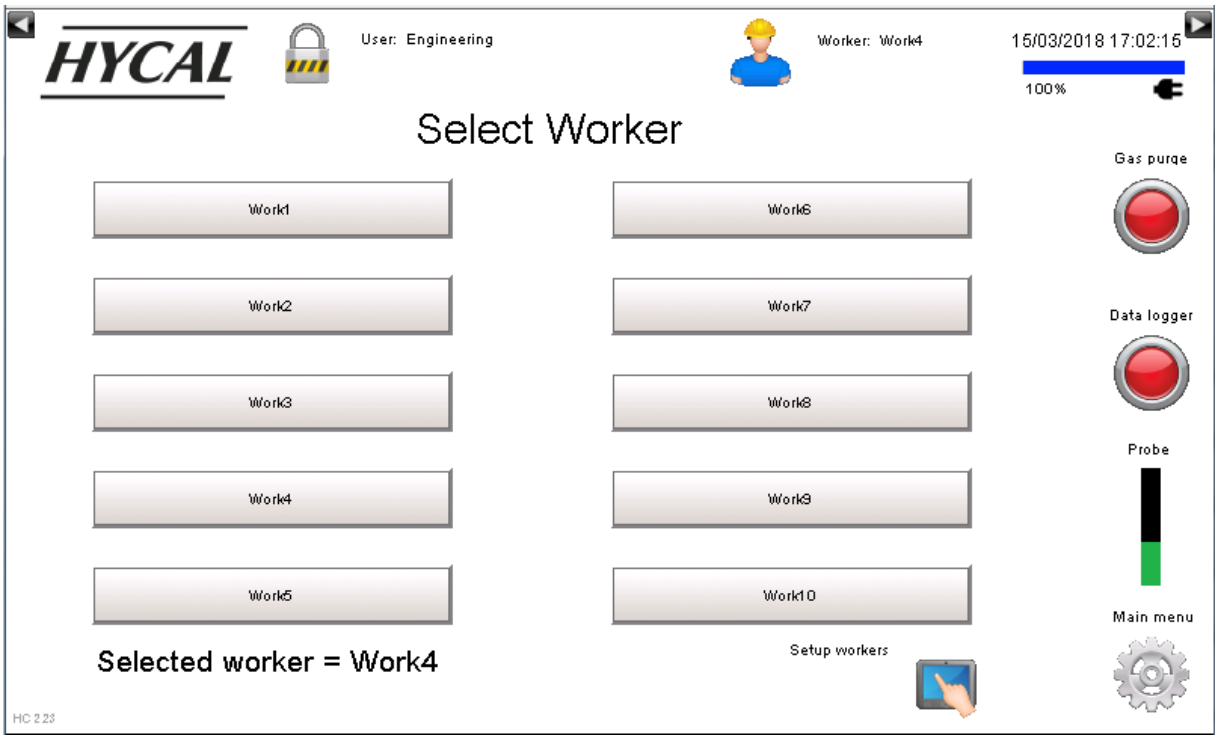


Figure 23: Worker selection screen

3.7.3.1 Setup worker names

To customise the worker names, log in as Engineering then press "Setup workers". Enter a name for each worker. Please note there is a limit of 10 characters including spaces.

3.7.4 Melt code

A melt code is recorded with each measurement by the data logger. The melt code appears on the following screens:

1. Data logger
2. Real-time chart
3. Diagnostics
4. Guided Measurement

To enter a new melt code, navigate to one of the above screens then press the text "Melt code" then enter alpha numeric text up to 10 characters. The PC software can identify and search measured data by melt code. All melt codes are automatically time stamped allowing two data sets with the same melt code to be differentiated.

3.7.5 Lot number

A lot number is logged with each measurement by the data logger. The melt code appears on the following screens:

1. Data logger
2. Real-time chart
3. Diagnostics
4. Guided Measurement

To enter a new Lot number, press the text "Lot No" then enter alpha numeric text up to 10 characters.

3.8 Real-time chart

The real-time chart provides a continuous real-time display of hydrogen and temperature. To view the chart press "Main menu" then "Chart". The selected alloy, melt code and lot number are displayed on the chart, these may be changed by pressing on the text. The chart time and hydrogen scales may be adjusted according to Table 5 by pressing the "Settings" icon in the top left corner of the chart.

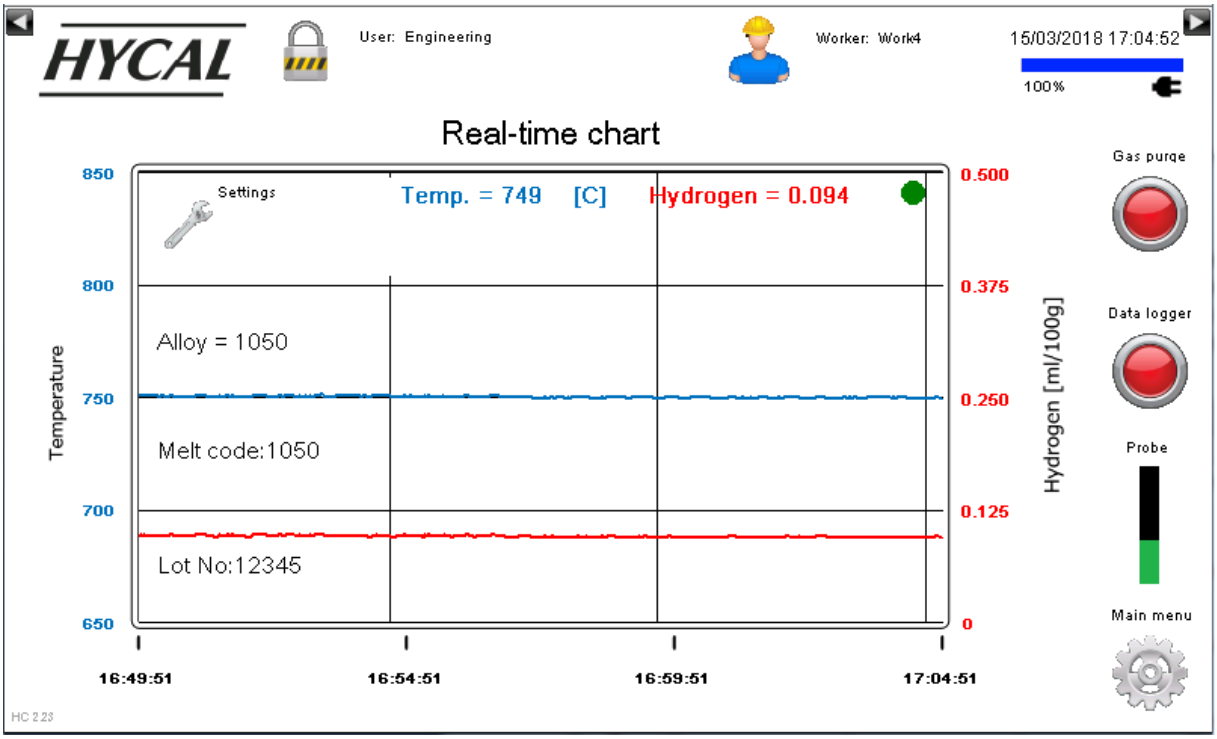


Figure 24: Real-time chart screen

Time	Hydrogen
5 minutes	0.10 ml/100g
15 minutes	0.20 ml/100g
30 minutes	0.30 ml/100g
1 hour	0.50 ml/100g
2 hours	1.00 ml/100g

Table 5: Time and hydrogen scale options

3.9 Data logger

The Hycal analyser has a built-in high capacity data logger which records the variables listed in Table 6 every 10 seconds.

Logged variables		
Instrument No.	Constant Z750	Sensor indicator
Date / time	Constant C	Pressure
Probe No	Constant D	Flow rate
Melt code	Final H	Purge time
Lot No.	H tolerance	Purge running
Worker	Final T	Stable reading
Alloy	T tolerance	Valid reading
Hydrogen	Analysis time [s]	Probe status
Temperature	Voltage	TC status
Temp units	pH2	pH2offset
Constant A	Z	Logged in user and alarm string
Constant B	Zref	Verification code
Constant Z700	Zdrift	Comment

Table 6: Data logger logged variables

The analyser can store up to 5 days of continuously logged data. When the memory is full the analyser will show a "Memory full" alarm (see Table 7) and will turn off the data logger. To resume logging, download the data to a PC computer then delete the data logger. Data logger memory status may be checked, and deleted if necessary, from the Settings screen (section 3.6.10).

Note: It is highly recommended to regularly transfer data to the PC software then clear the data logger memory in order to reduce data transfer times.

The status of the data logger is indicated by the data logger icon on the right-hand side of the screen:

- Red = Data logger is off
- Green = Data logger is on

The data logger does not start automatically and is off by default when the analyser starts up. To start or stop the data logger either press the "Data logger" icon on the right hand side of the screen or press the middle button on the side of the analyser (see Figure 3).

3.9.1 Data logger chart

The data logger chart allows the logged hydrogen and temperature data to be viewed as it is logged and allows archived data to be viewed. To view the data logger chart press "Main menu" then "Data logger". The chart will only show logged data so will not display live data if the data logger is off.

Pressing the "Settings" icon in the top left corner of the chart shows the "Data logger settings" menu (Figure 19) which shows the % of the data logger memory used and the remaining log time in days, hours and minutes. The logger may also be deleted. Similar to the real time chart, the chart time and hydrogen scales may be adjusted according to Table 5. The selected alloy, melt code and lot number are displayed on the chart, these may be changed by pressing on the text.

In contrast to the real-time chart, the data logger chart display has a quantised ("stepped") appearance when a short time scale is selected (e.g. 5 minutes), this is due to the 10 second data log interval.

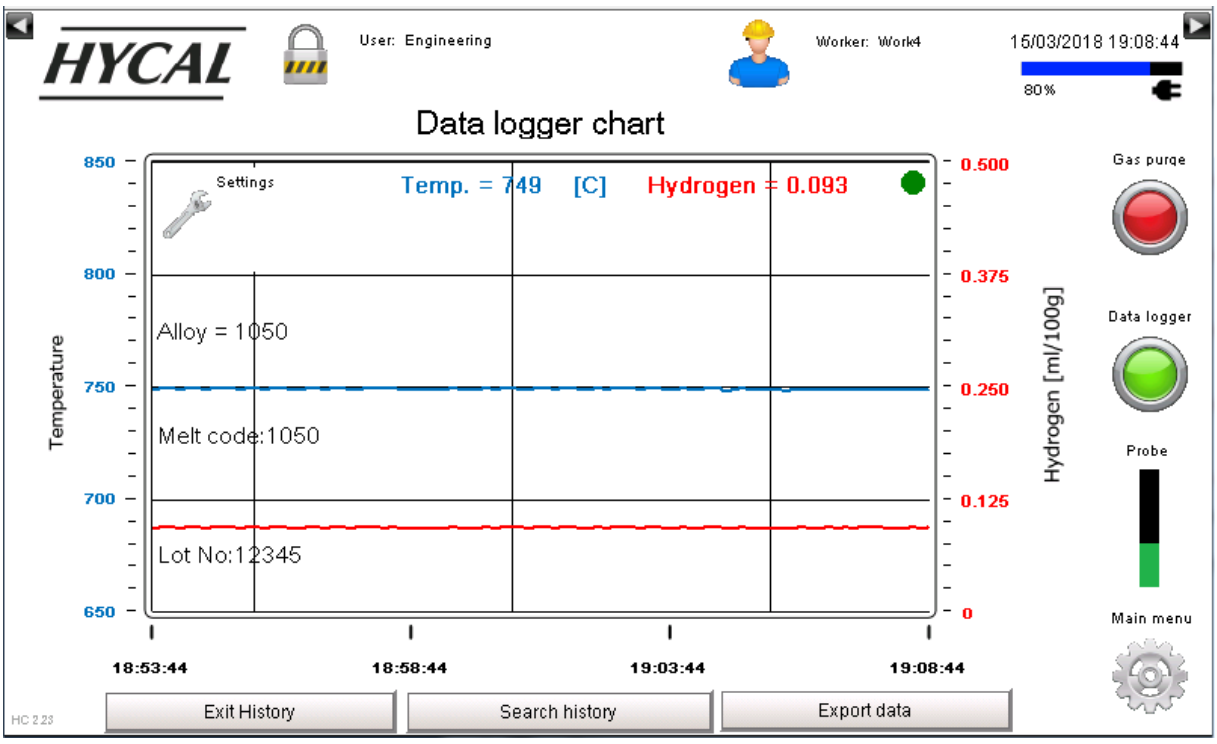


Figure 25: Data logger chart screen

3.9.1.1 View historical data

To view historical data stored in the data logger press the "Search history" button. The "History Time Settings" menu will appear (see Figure 26). Press on the date / time values, use the + and - buttons to select the desired period of time, then press "OK" to display the data. To exit History mode and return to the real-time view, press "Exit history".

3.9.1.2 Exporting data

The data logger may be exported to a USB memory stick or to the Hycal's internal FTP server. The export process produces a comma separated CSV file which may be opened directly in Microsoft Excel or transferred to the Hycal PC software (see section 9.4). To export the database, press "Export data"; the data export window will appear as shown on Figure 27. The duration of the export process is estimated at the bottom of the window and can be from a few seconds to several minutes depending on the size of the database. For faster data export times, delete the data logger's memory regularly as detailed in section 3.6.10.

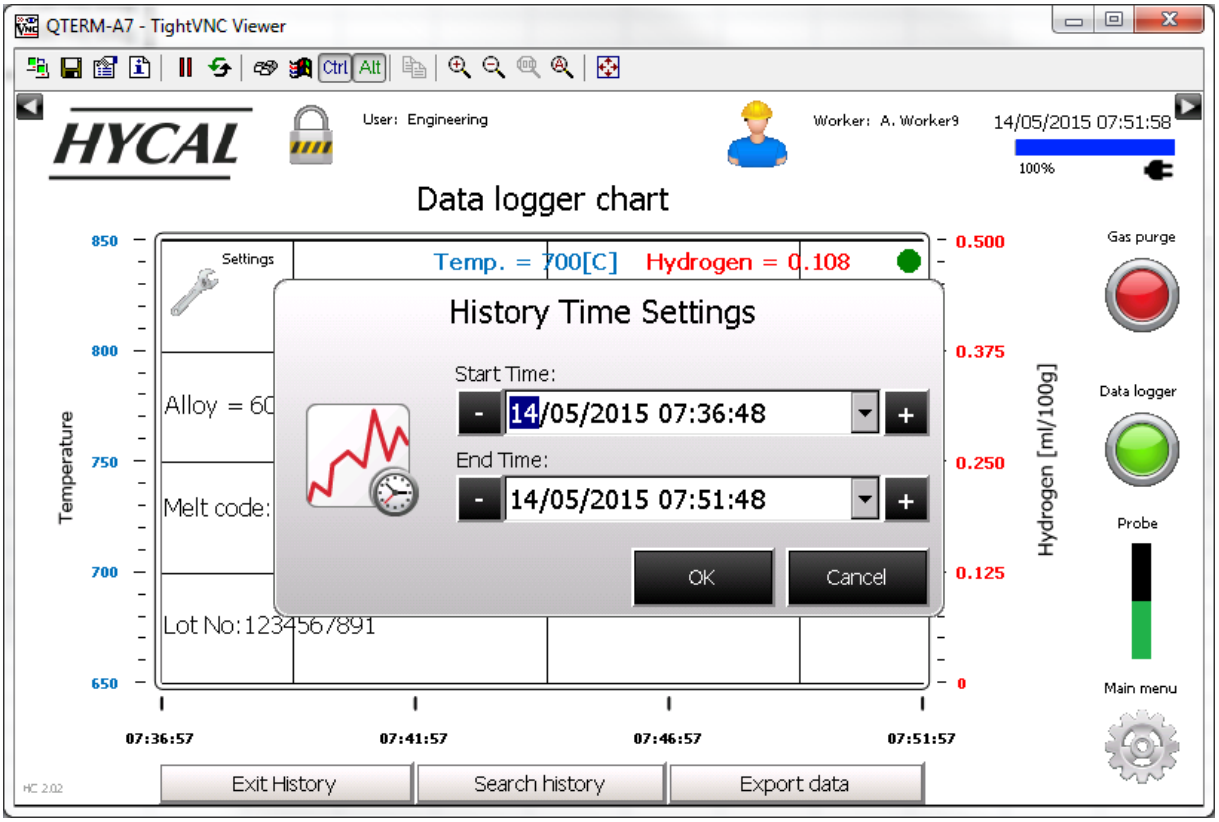


Figure 26: Viewing data logger history

3.9.1.2.1 USB export

Insert a USB memory stick into the USB port on the side panel of the Hycal analyser as shown on Figure 3 then press "Export USB". The analyser will export the database then copy it to the USB memory stick. The data is located in the following directory on the USB stick "[USB drive letter]:\DatabaseExport\Data Loggers\HycalLog.csv".

3.9.1.2.2 FTP export

Press "Export FTP" and wait for the export process to finish. The file may then be transferred to the PC software by FTP or retrieved directly by logging onto the Hycal's FT server:

- FTP address: [Hycal's IP address]\DatabaseExport\Data Loggers\HycalLog.csv
- FTP username: Engineering
- FTP password: 100

Please note that the FTP username and password are factory set and will **not** change if the Engineering password is changed according to the instruction in section 3.4.3.

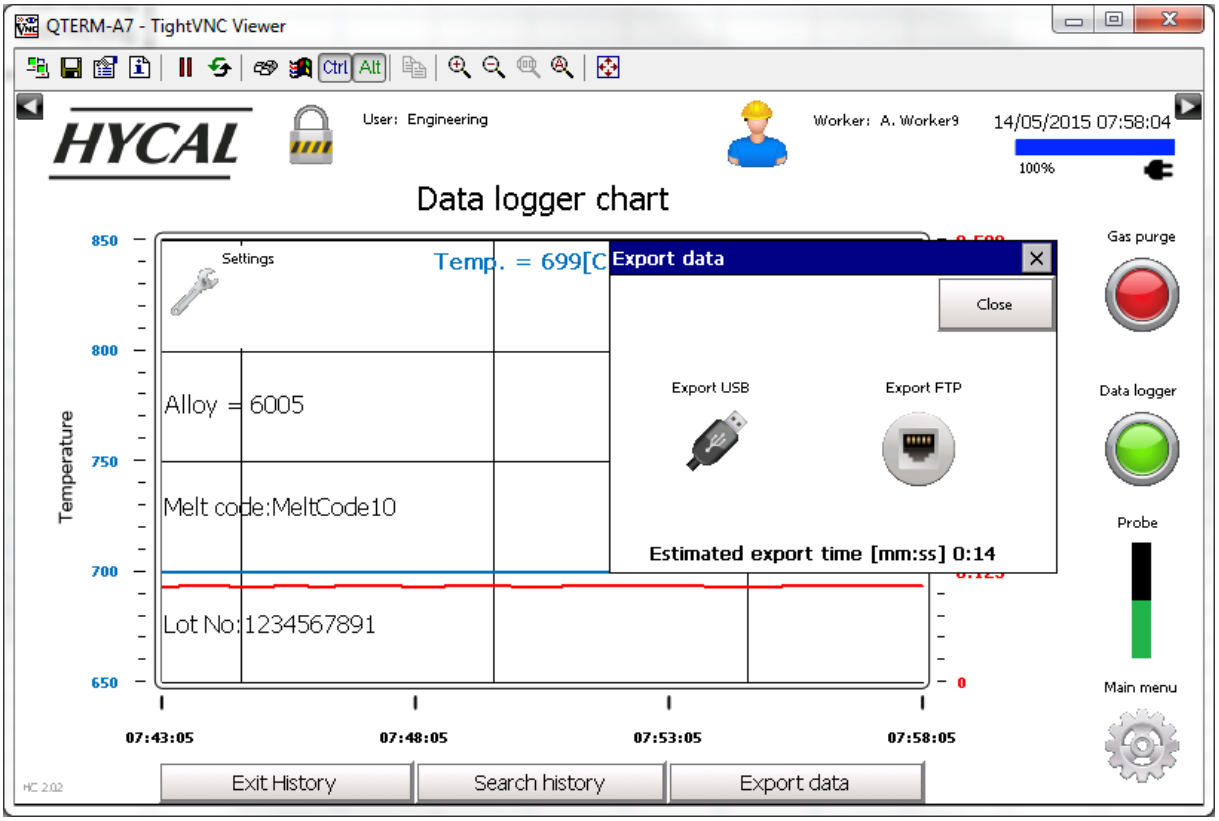


Figure 27: Data logger export

3.10 High visibility mode

The Hycal analyser includes a high visibility mode to maximise readability of the hydrogen and temperature readings from extended distances (see Figure 28). To enter high visibility mode, press "Main menu" in the bottom right then press "Big display". To exit, press the "Exit" button in the top right.

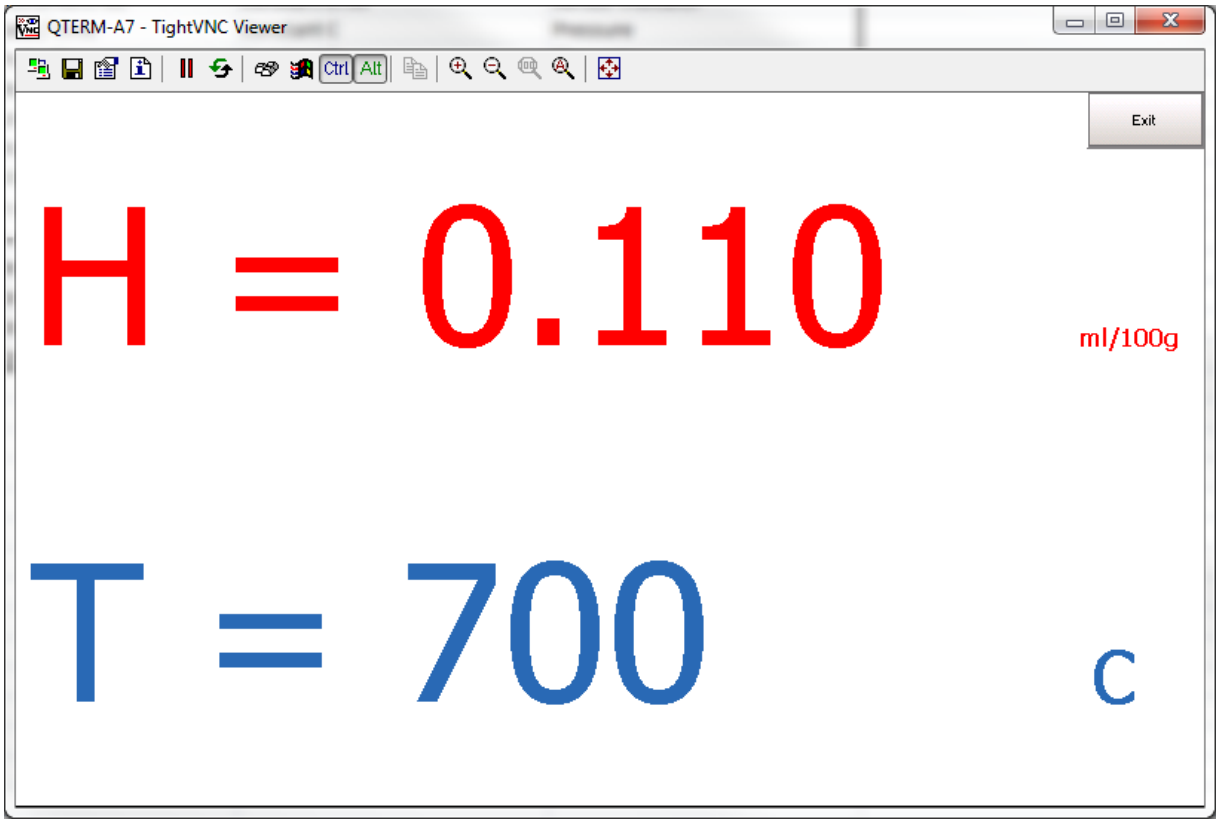


Figure 28: High visibility mode

3.11 Alarms

The Hycal analyser is equipped with sophisticated On-Board Diagnostic (OBD) hardware and algorithms which continuously check that the probe and analyser are operating properly. If the analyser detects a problem, then this will trigger an alarm event (see Figure 29):

1. A flashing red alarm icon will appear
2. An alarm information screen will appear, showing:
    a. Alarm Code
    b. Alarm title
    c. Possible reasons for the alarm
    d. Suggested actions to correct the problem

3.11.1 Alarm list screen

After an alarm has become active it must be acknowledged. Close the alarm information screen, press "Main menu" then "Alarms" to show the alarm list screen. Any active alarms are filled in red. To acknowledge an alarm, select it the press "Ack selected". If problem has not been resolved but the alarm is acknowledged, then the fill colour will change from red to green and the flashing alarm icon

will disappear. If the cause of the alarm is resolved, it will not be filled but will remain on the alarm list.

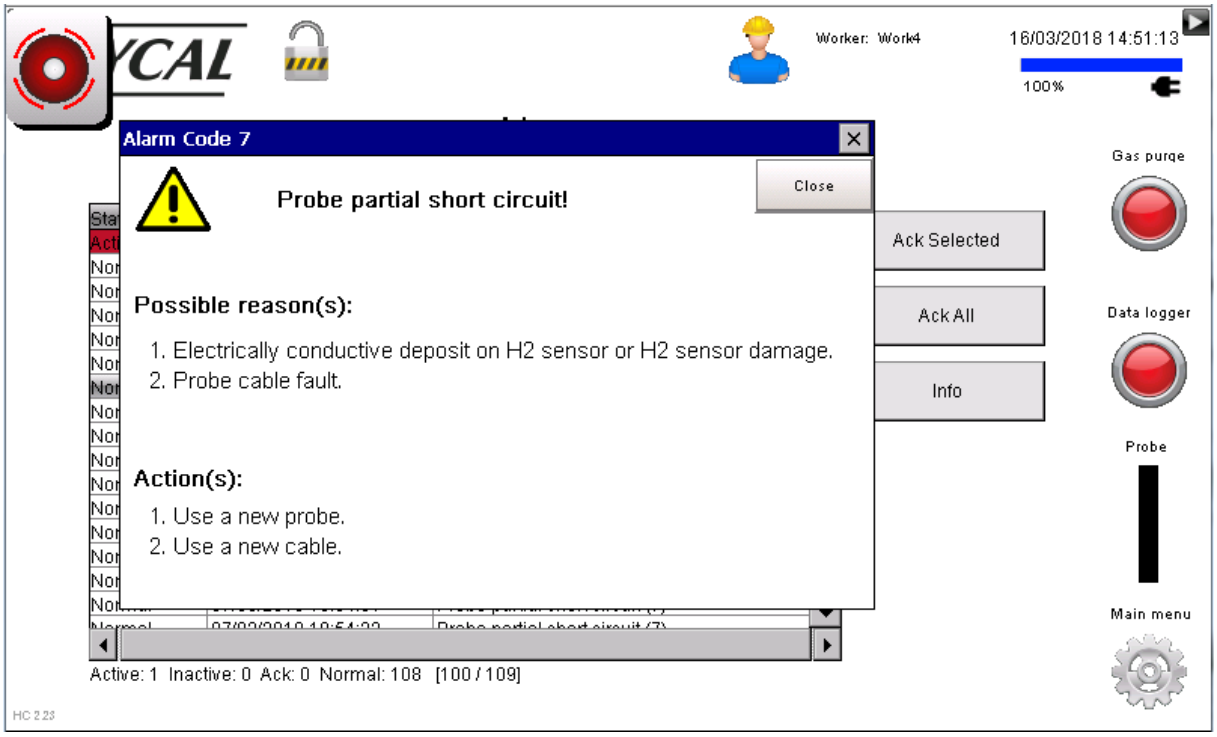


Figure 29: Alarm event

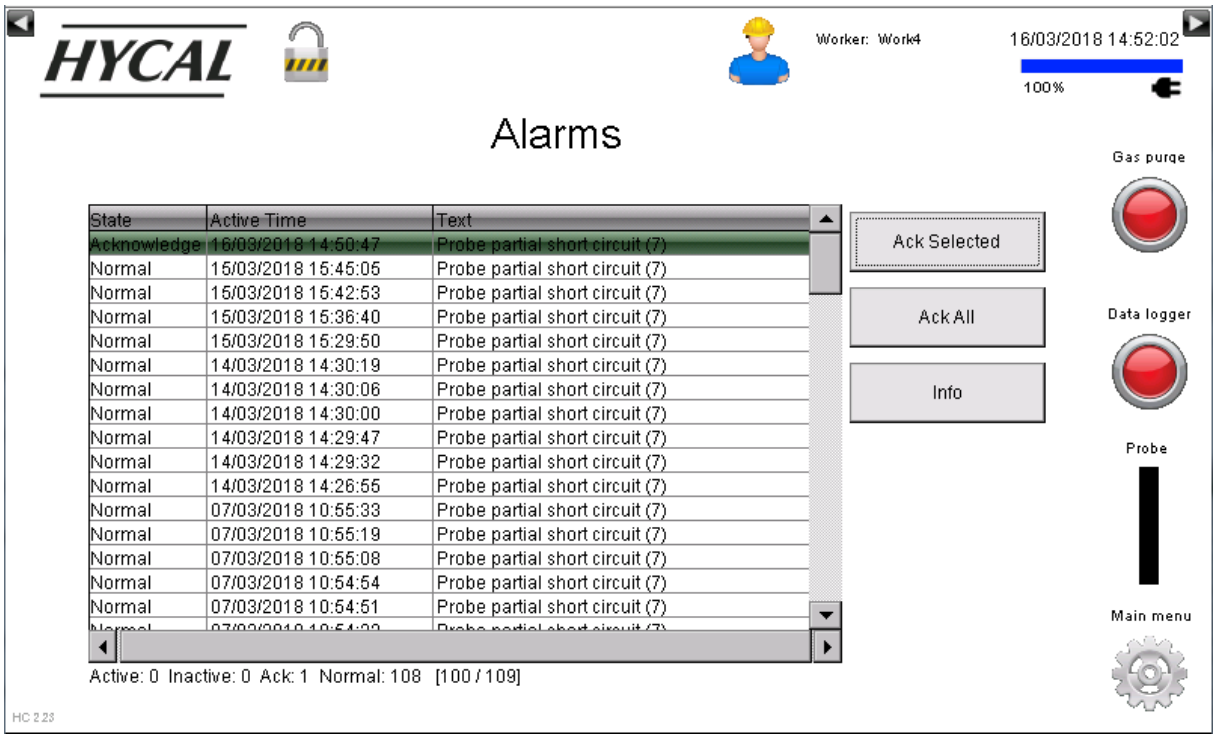


Figure 30: Alarm list screen

3.11.2 Hycal analyser alarms

Table 7 lists all Hycal analyser alarms.

Message	Purge gas flow is too low!
Alarm code:	1
Possible reason(s):	1. Probe cable not properly connected to analyser 2. Probe is blocked (e.g. flux / condensed volatiles etc.). 3. Blockage in probe cable.
Action(s):	1. Disconnect probe from probe cable. Press "Gas purge" and verify that gas flowing. 2. Use a new probe. 3. Use a new cable.
Message	Purge gas flow is too high!
Alarm code:	2
Possible reason(s):	1. Gas leak at joint between probe and cable (e.g. O ring). 2. Punctured gas delivery tube (inside cable). 3. Graphite cap at probe tip has failed.
Action(s):	1. Check probe is properly connected and engaged with the cable. 2. Check probe cable is not damaged (burnt or punctured). 3. Use a new probe.
Message	Purge gas pressure is too low!
Alarm code:	3
Possible reason(s):	1. Internal gas cylinder is empty. 2. External line pressure is too low.
Action(s):	1. Check internal cylinder pressure. Refill if necessary. 2. If using external gas supply, check line pressure is 3 - 10 bar.
Message	Purge gas pressure is too high!
Alarm code:	4
Possible reason(s): Action(s):	System error. Contact Hycal representative.
Message	Probe impedance too low!
Alarm code:	5
Possible reason(s):	1. Aluminium has entered the probe. 2. Probe cable is damaged.
Action(s):	1. Check probe for aluminium ingress. 2. Check probe cable for damage. 3. Use a new probe.

Message	Probe impedance is too high!
Alarm code:	6
Possible reason(s):	1. Probe has reached maximum use. 2. H2 sensor error. 3. Probe cable is damaged.
Action(s):	1. Use a new probe. 2. Check probe is properly connected to cable. 3. Check probe cable is not damaged.
Message	Probe partial short circuit!
Alarm code:	7
Possible reason(s):	1. Electrically conductive deposit on H2 sensor or H2 sensor damage. 2. Probe cable fault.
Action(s):	1. Use a new probe. 2. Use a new cable.
Message	Probe has reached maximum use!
Alarm code:	8
Possible reason(s):	1. Probe has reached maximum use.. 2. Probe cable fault.
Action(s):	1. Use a new probe. 2. Use a new cable.
Message	Data logger nearly full!
Alarm code:	9
Possible reason(s):	Data logger memory is nearly full.
Action(s):	1. Download data to PC using Hycal PC software. 2. Delete data logger (Settings screen).
Message	Data logger memory full!
Alarm code:	10
Possible reason(s):	Data logger memory (5 days continuous measurement) is full. Data cannot be recorded until memory has been cleared.
Action(s):	1. Download data to PC using Hycal PC software. 2. Delete data logger (Settings screen).
Message	No Guided Measurements active!
Alarm code:	[Warning only]
Possible reason(s):	All 3 Guided Measurement types (measurement / degassing / calibration) are turned off.
Action(s):	1. Navigate to Settings and turn on at least one Guided Measurement type.

Table 7: Hycal analyser alarms

3.12 Diagnostics

To assist with troubleshooting, a “Diagnostics” screen is available. This collects all data relevant to hydrogen measurement (plus additional information) and displays it on a single screen to quickly and easily identify problems, should they occur. To access the "Diagnostics" screen, press "Main menu" then "Diagnostics".

The Diagnostics screen shows a "pH2" reading; this is the partial pressure of hydrogen measured by the hydrogen cell inside the Hycal probe in units of atmospheres. This is valuable when checking hydrogen cell accuracy when purging with a calibration gas of known hydrogen partial pressure.

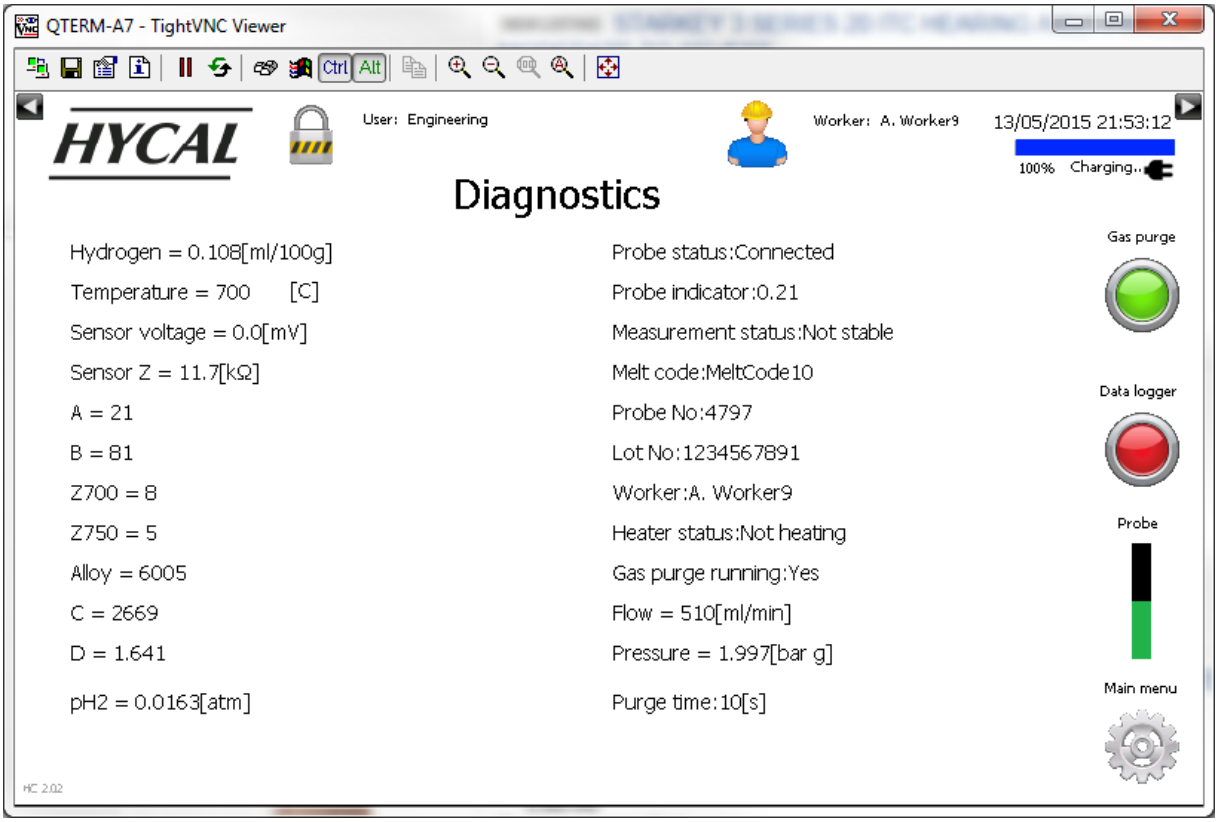


Figure 31: Diagnostics screen

4 Measurement Procedure

4.1 Prerequisites

(i) Ensure that the melt temperature is <800C.

(ii) Check that the Hycal has a gas supply

a. If running from the Hycal's internal gas cylinder, ensure that the gas selector valve is set to "HP cylinder" and check the pressure indicator (see Figure 4). If the cylinder is empty, then follow the procedure in section 2.2 to fill with gas.

b. If running from a low-pressure gas line, ensure that the gas selector valve is set to "LP inlet" and that the gas line is connected and pressurised with purge gas at 3 - 10 bar.

(iii) Switch on the Hycal analyser. The indicator LEDs on the Hycal's front panel will flash in sequence to indicate that the analyser is starting. If the red LED flashes this indicates that the battery is empty and requires charging (see section 3.1.1).

(iv) If the probe heater is on, ensure that it is turned off before proceeding

4.2 Procedure

1. Ensure that the following analyser settings are set correctly and set if necessary:

   a. Alloy (section 3.7.1)

   b. Probe calibration (section 3.7.2)

   c. Worker (section 3.7.3), Melt code (section 3.7.4), and Lot number (section 3.7.5)

2. Position the arm appropriately over the melt.

3. Insert a Hycal probe into the arm's probe clamp. Slide the probe vertically so that it is 10-20cm above the melt and tighten the arm's probe clamp to secure the probe.

4. Press the "Gas purge" button on the Hycal analyser and lower the probe into the melt to a depth of 10 - 15cm whilst the purge gas is flowing.

5. Wait for the hydrogen reading to stabilise (green circular marker appears next to the hydrogen reading) .

6. To check the hydrogen reading, press the "gas purge" button, wait for the hydrogen to stabilise, and compare the reading with the previous value. Repeat this procedure until two consecutive readings agree.

4.3 Precautions

1. Do not immerse deeper than 30cm (i.e. do not immerse deeper than the ceramic section of the probe).

2. Avoid impact with the probe.

3. Do not exceed the probe's maximum rated temperature of 800°C. Damage will occur above 830°C.

4. Do not expose the analyser to temperatures above 70°C.

4.4 Use with a degasser

Position the probe as far away as possible from the rotor, ideally 75cm – 1m. Mounting too close to the rotor may result in damage to the probe due to collision, and erratic readings caused by bubbles of purging gas passing beneath the probe.

5 Guided Measurement mode

Guided Measurement is a special mode that guides the operator through the measurement setup procedure prompting for all necessary information. The Hycal then automatically performs all necessary measurement preparation steps (purge cycles, delays etc.), conducts a pre-defined number of measurement analyses, and records the data.

The measurement analysis starts when the hydrogen and temperature readings have stabilised according to the stabilisation parameters set in section 3.6.6. The analyser then records hydrogen and temperature readings for the "Analysis time" specified in Guided Measurement settings. After the analysis time has elapsed, the analyser examines the logged data and determines the Guided Measurement results detailed in Table 8.

Result	**Detail [Refers only to data collected during the Guided Measurement analysis time]**
Hydrogen	Average (mean) of the hydrogen readings
H span	Difference between the maximum and minimum hydrogen readings
Temperature	Average (mean) of the temperature readings
T span	Difference between the maximum and minimum temperature readings

Table 8: Guided Measurement results

All Guided Measurement data is recorded automatically by the data logger. Guided Measurement is ON by default and may be accessed by pressing the "Start measurement" icon on the Home screen (see Figure 10).

5.1 Guided Measurement sequence

The Guided Measurement event sequence is shown on Figure 32. Event settings are configured in advance by the engineer and then occur automatically when the operator performs a Guided Measurement.

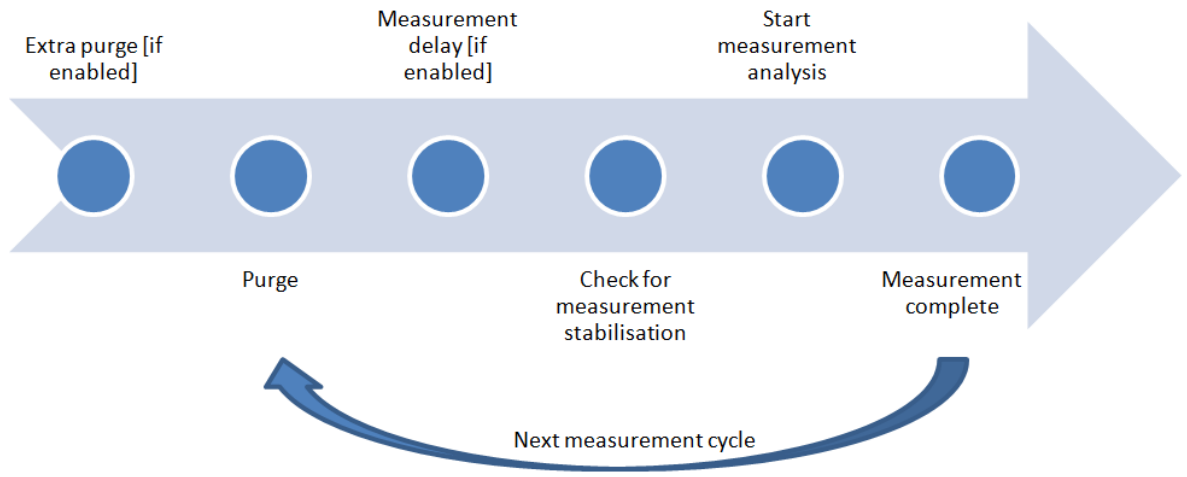


Figure 32: Guided Measurement event sequence

5.2 Guided Measurement settings

The Guided Measurement settings screen is located at Settings, Guided Measurement settings (section 3.6.11).

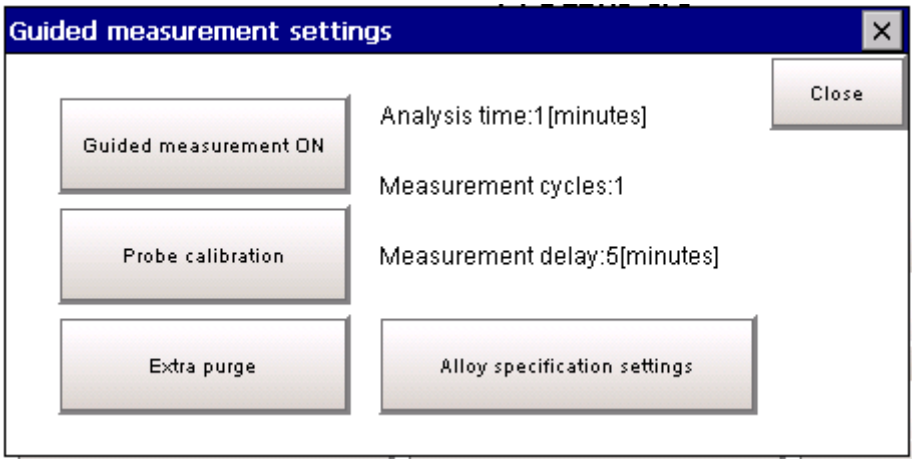


Figure 33: Guided Measurement settings

5.2.1 Guided Measurement ON / OFF

Default = ON. Turns the Guided Measurement feature turned on or off. If Guided Measurement is off, then the "Start Guided Measurement" icon is removed from the "Measurement" screen and it is not possible to start a Guided Measurement.

5.2.2 Analysis time

Default = 1 minute. Sets the measurement analysis time.

5.2.3 Measurement cycles

Default = 1 cycle. Sets the number of measurement cycles. If set to >1 the Hycal will automatically repeat the measurement for the number of cycles set here (see Figure 32).

5.2.4 Extra purge

Default = OFF. When enabled, it performs an additional gas purge followed by a pause, before performing the first measurement. This is to combat moisture release from a new probe when first immersed into the melt and is therefore not repeated for each measurement cycle (see Figure 32). The following may be set:

- Duration of extra purge, in seconds
- Duration of pause time, after the extra purge, in seconds

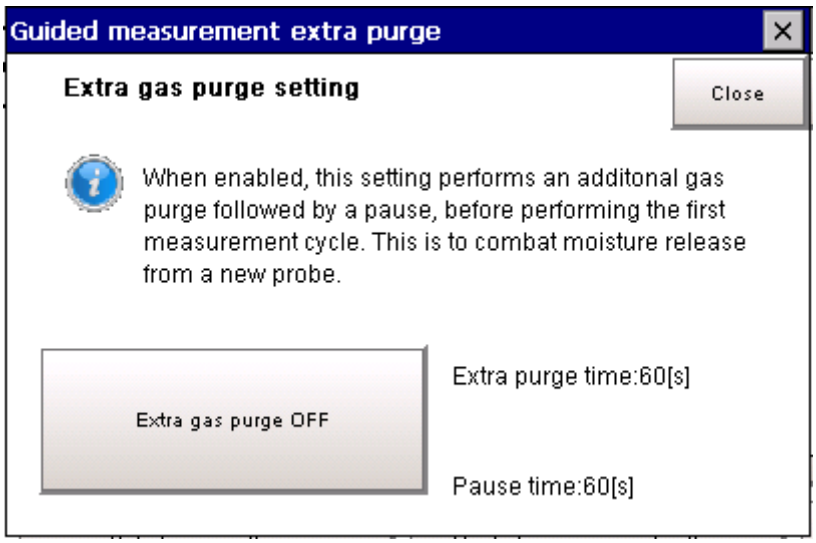


Figure 34: Extra purge settings

5.2.5 Measurement delay

Default = 0 minutes (OFF). Sets a programmable delay immediately prior to the measurement stability check. In certain alloys the measurement can appear to stabilise at an initial plateau before increasing again, and then stabilising at the true equilibrium hydrogen value (S-shaped response). This setting can mitigate against this effect.

5.2.6 Probe calibration

Default = "Normal". This means that the operator must ensure that the correct probe constants are entered. However, in some cases different probes will be assigned individual measuring stations and it is not convenient to re-enter the probe calibration constants when moving the Hycal analyser to a different station. Setting the probe calibration mode to "Stations" allows the engineer to enter the probe calibration constants for each station in advance, so that operator simply needs to select the correct station before making a measurement.

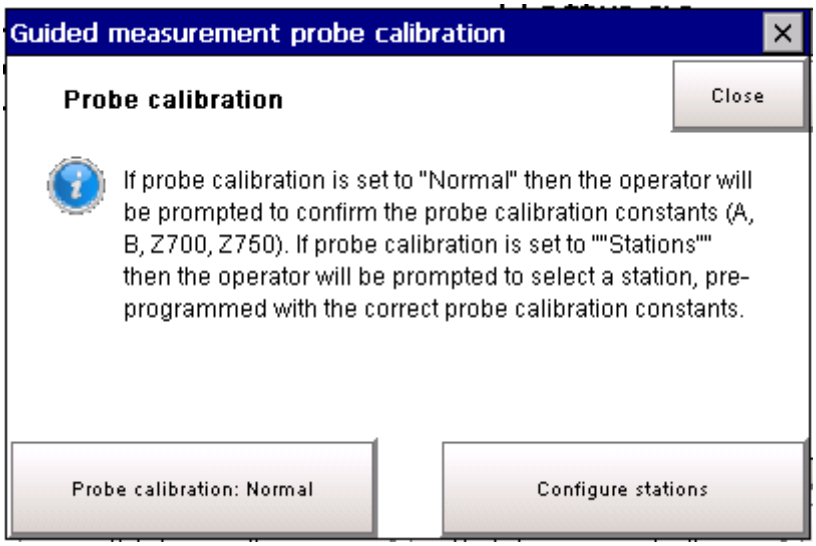


Figure 35: Guided Measurement Probe calibration setting

Up to 4 stations may be configured, by pressing the "Configure stations" button. Each station is set to active or inactive and is given an ID, and a set of probe data as shown in Figure 36.

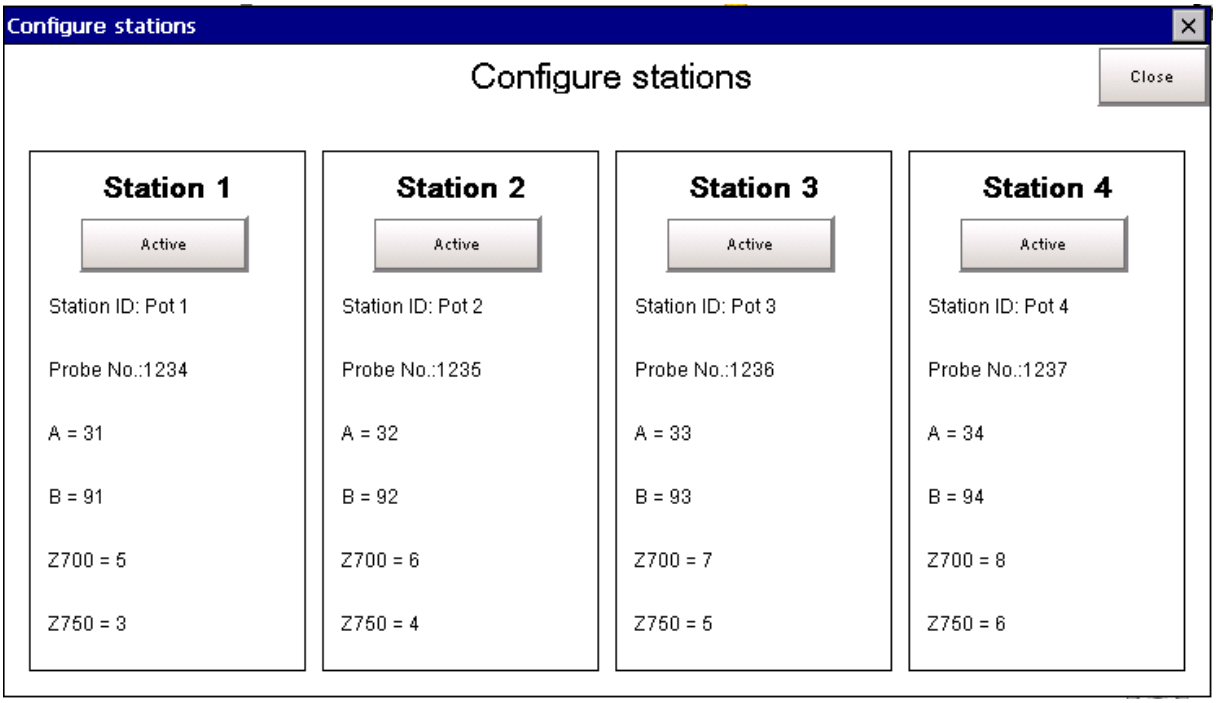


Figure 36: Guided Measurement station configuration

5.2.7 Alloy specification

This setting (off by default) allows a top and bottom hydrogen limit to be specified.

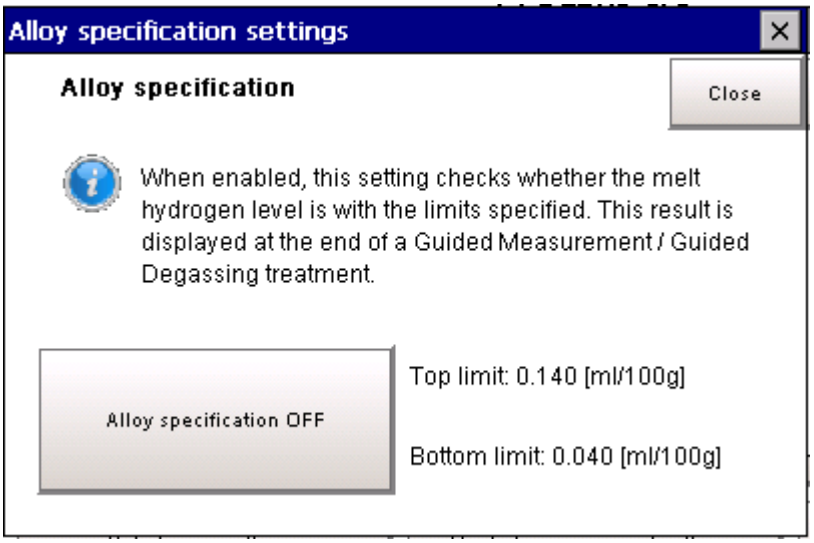


Figure 37: Guided Measurement alloy specification settings

5.3 Guided measurement steps

5.3.1 Step 1 - Select worker

The user must select one of the displayed workers before proceeding or alternatively can cancel the measurement by pressing the "Close" icon in the top right corner. The list of workers may be changed as detailed in section 3.7.3. After pressing a worker button, the worker name appears in the bottom left of the screen and the Continue button appears, allowing the user to proceed to the next step.

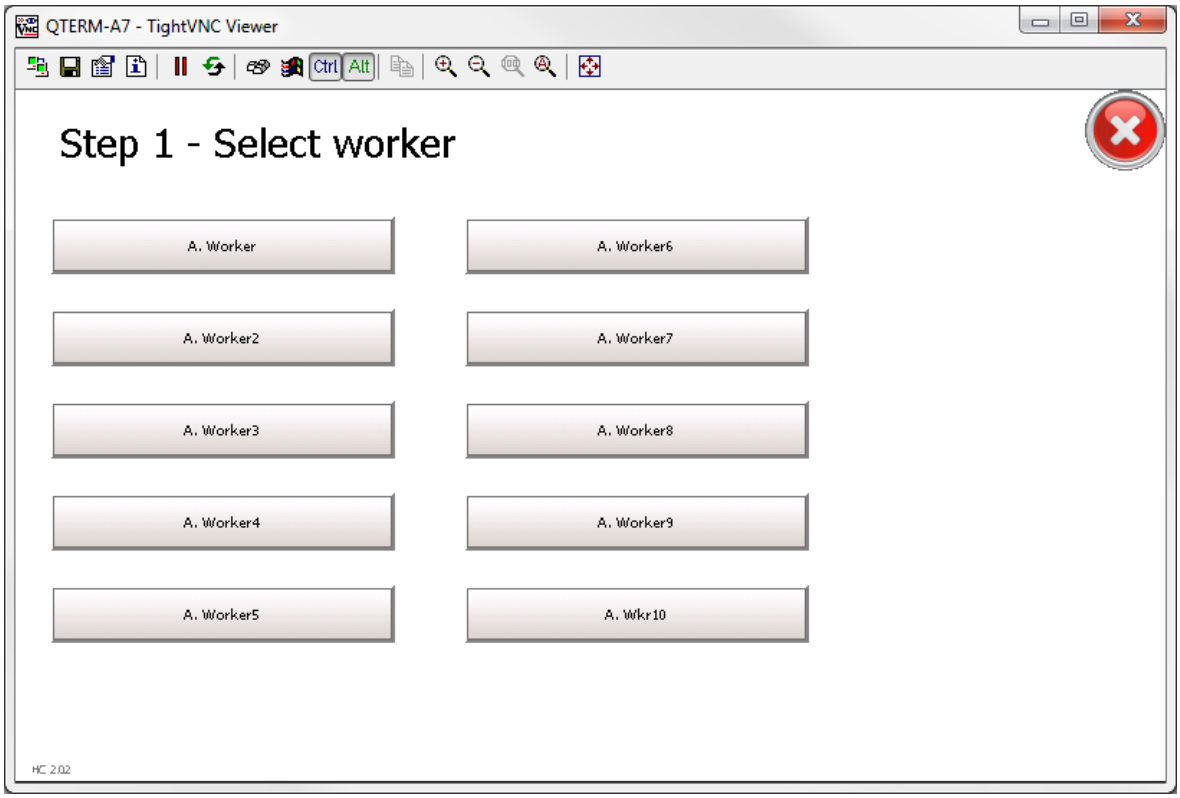


Figure 38: Step 1 - Select worker (before selection)

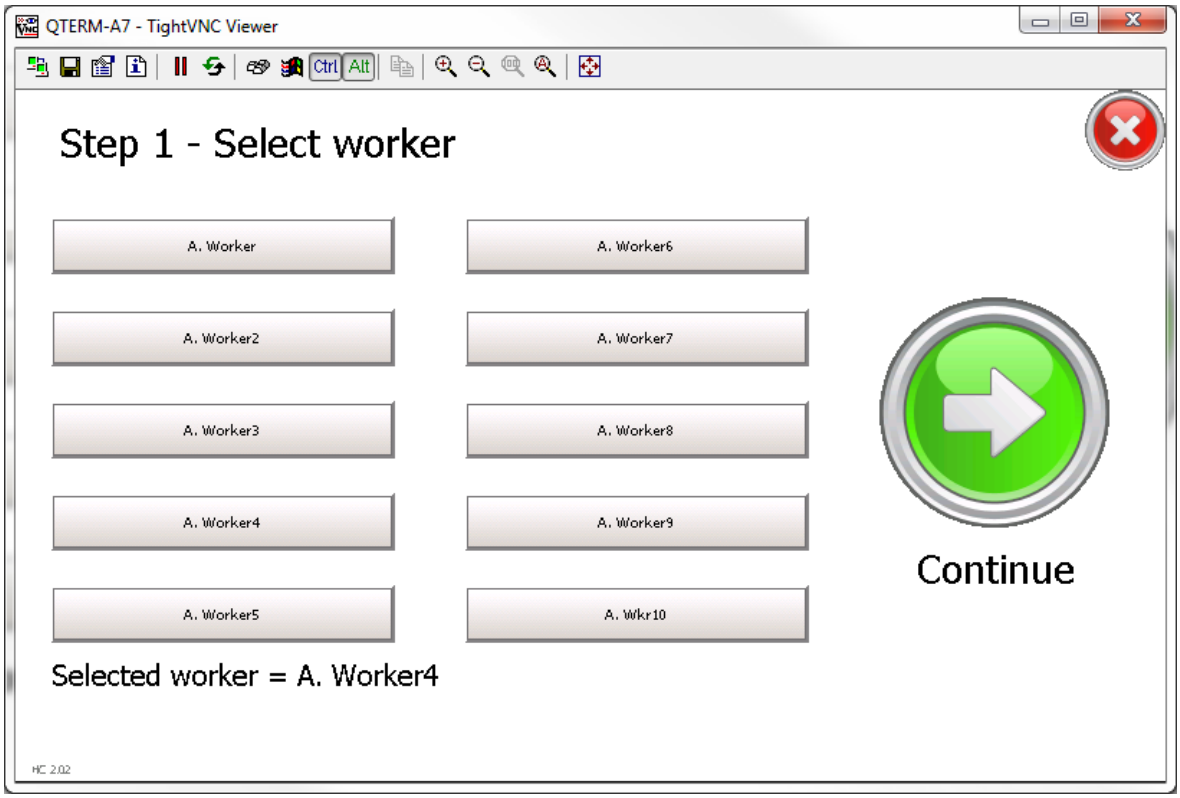


Figure 39: Step 1 - Select worker (after selection)

5.3.2 Step 2 - Enter Lot number

The user must press the Lot Number field then either:

1. Type in a new lot number (maximum 10 alpha numeric characters) then press Enter (circled in red on Figure 40)

   OR

2. Confirm the existing lot number by pressing Enter or Esc

After doing so the Continue button appears, allowing the user to proceed to the next step. If a mistake is made the user may press the Back button in the bottom left corner of the screen to return to, and edit, the previous step.

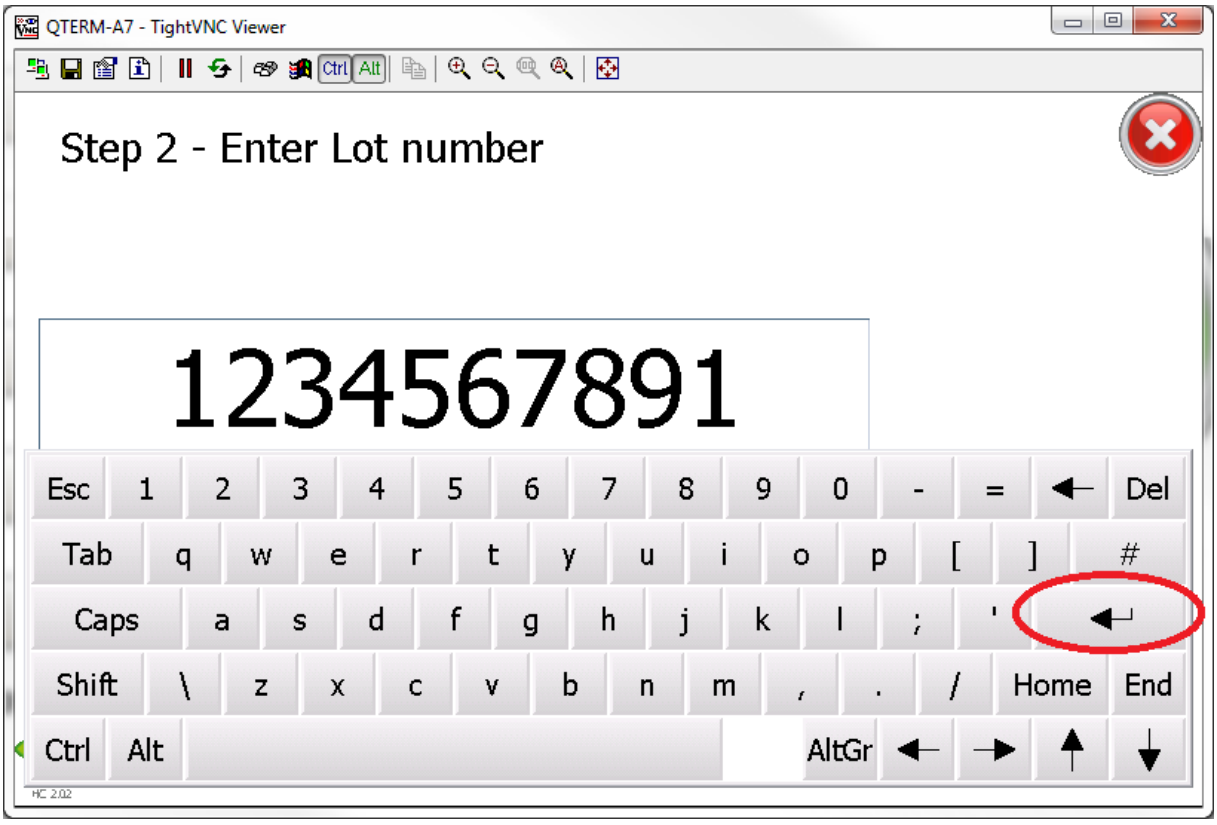


Figure 40: Step 2 - Enter Lot number

5.3.3 Step 3 - Select alloy

The user must select an alloy by choosing an alloy group then an alloy (see section 3.7.1). After selection, the Continue icon will appear allowing the user to proceed to the next step.

Note: Even if the desired alloy is already selected, the user must still press the alloy button to confirm the selection otherwise the Continue button will not appear.

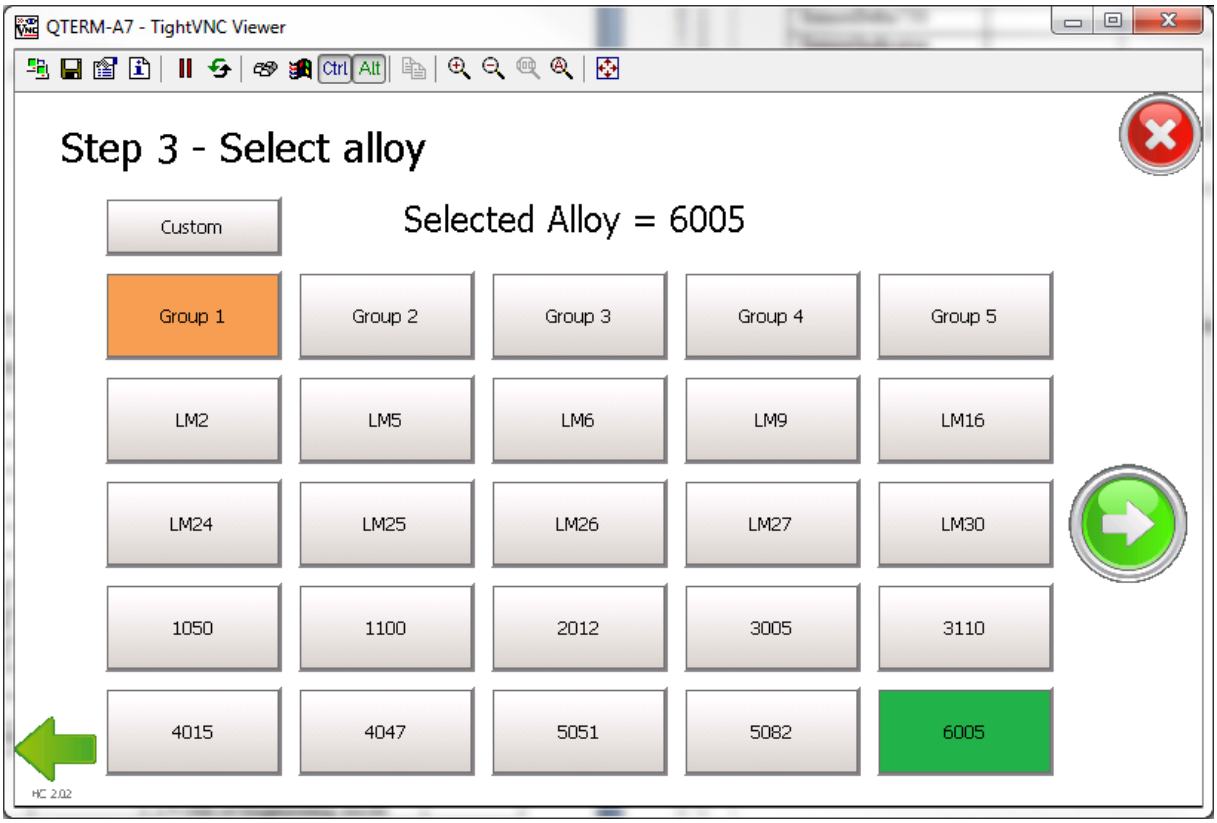


Figure 41: Step 4 - Select alloy

5.3.4 Step 4 - Enter Melt code

Similar to the Lot number screen, the user must press the Melt code field then either:

1. Type in a new melt code (maximum 10 alpha numeric characters) then press Enter

   OR

2. Confirm the existing melt code by pressing enter or Esc. By default, the existing melt code is set to the selected alloy name.

After doing so the Continue button appears, allowing the user to proceed to the next step. If a mistake is made the user may press the Back button in the bottom left corner of the screen to return to, and edit, the previous step.

5.3.5 Step 5 - Check probe calibration

If probe calibration is set to "Normal" (see section 5.2.6) then the user should check that the probe details are correct and change them if necessary by pressing the relevant field and entering the required information as per Figure 42.

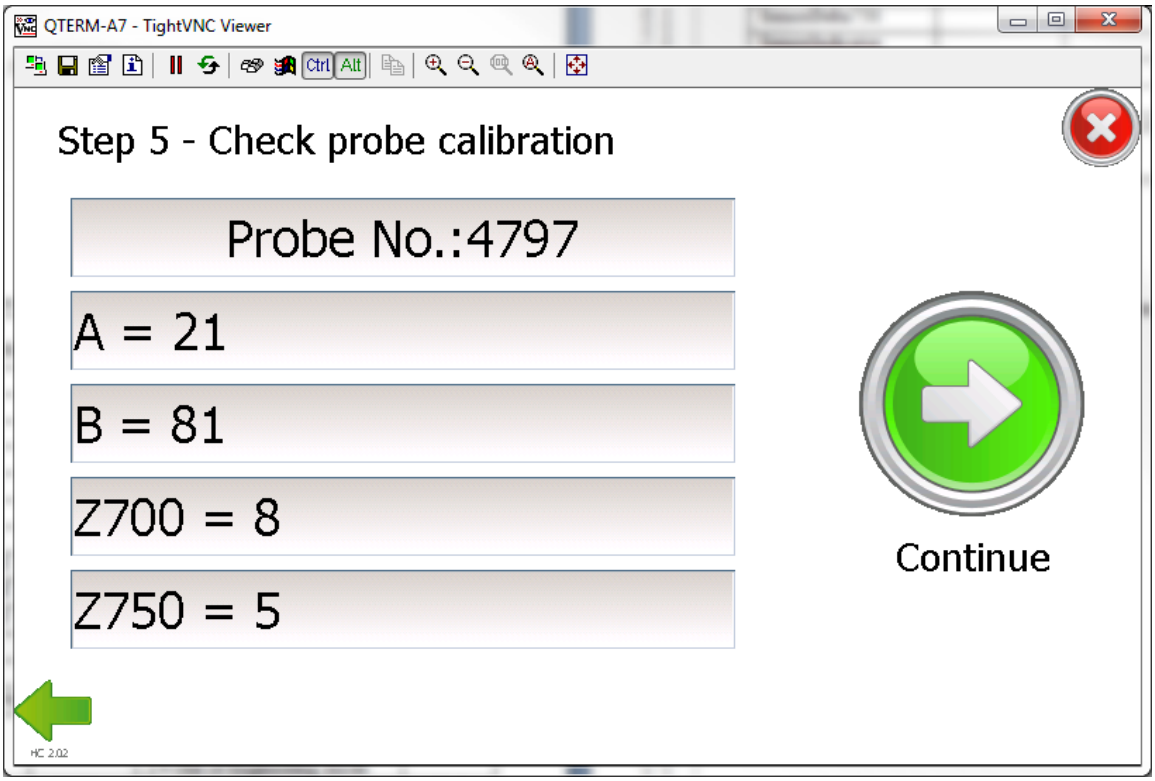


Figure 42: Probe calibration screen: "Normal" mode

If probe calibration is set to "Stations" (see section 5.2.6) then the user should press the relevant station button as per Figure 43.

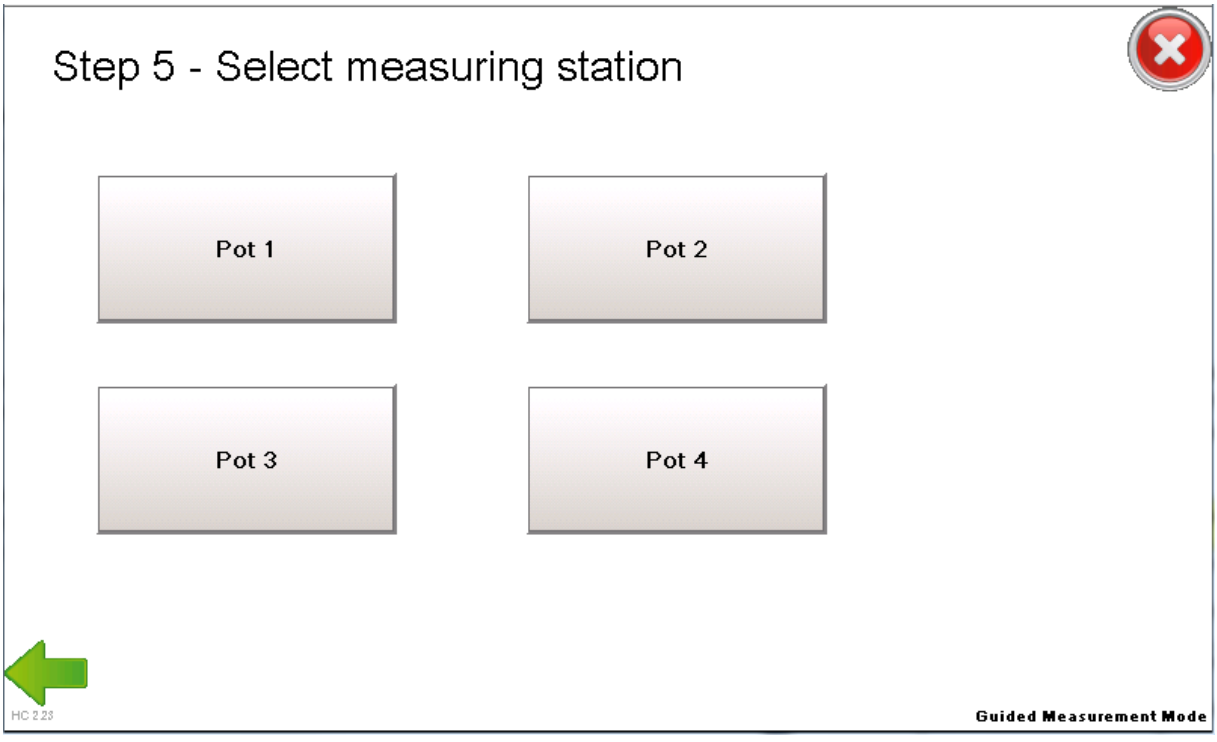


Figure 43: Probe calibration screen: "Stations" mode

5.3.6 Step 6 - Prepare for measurement

At this stage all the required information has been entered. The user can still press the Back button and make corrections if necessary. The messages displayed will depend on the probe status as shown on Table 9.

Probe status	Message	Detail
Probe not connected	Connect probe [Continue button not shown]	User must connect probe before proceeding
Probe connected and not immersed in molten aluminium	Probe status: Connected DO NOT IMMERSE PROBE! Position prove above melt ready for immersion then press Continue [Continue button shown]	This is to ensure that the purge gas is flowing through the probe when it is immersed. When the user presses Continue the analyser will start the purge gas and this will stay on until the probe temperature is >600C
Probe connected and already immersed in molten aluminium (temperature > 600C)	Probe status: Connected [Continue button shown]	Probe is already immersed so analyser does not need to start the purge gas prior to immersion. When the user presses continue the measurement will start

Table 9: Step 6 - Probe status prior to immersion

5.3.7 Step 7 - Measurement

Figure 44 shows the measurement screen, features are summarised in Table 10.

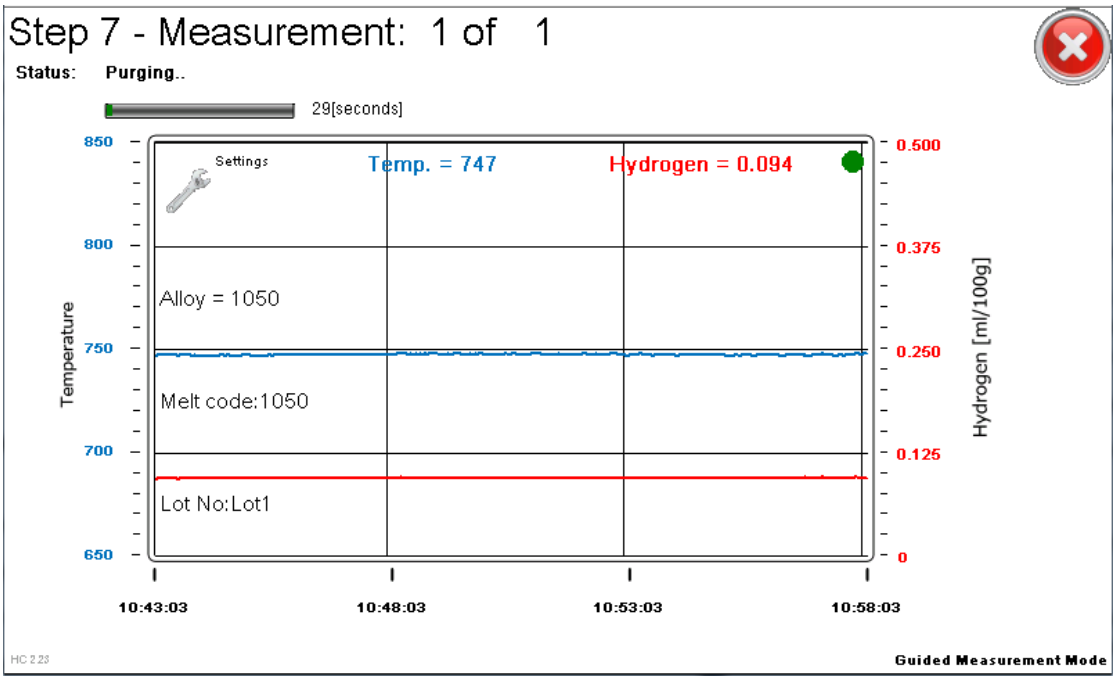


Figure 44: Measurement screen

Feature	Detail
Measurement number	Current measurement number and total measurements to be performed are shown at the top of the screen.
Status text	Status text at the top of the screen informs the operator about which measurement stage is in progress (e.g. purging, stabilising, measuring).
Progress bar	Progress bar at the top of the screen shows the progress of the stage detailed by the status text. Pressing on the progress bar shows a countdown timer in seconds.
Settings	Settings icon at the top left of the chart allows chart time and hydrogen scale to be changed.
Probe indicator	The probe indicator is shown at the bottom right of the screen. It cannot be pressed to show the probe screen because probe calibration details have already be entered / confirmed in step 5 (section 5.3.5).
Alloy, Melt code, Lot No.	These are shown on the chart but cannot be changed as these details have already been confirmed in the previous Guided Measurement stages.
Stabilisation indicator	Green circle appears to the right of the displayed hydrogen reading when hydrogen and temperature have stabilised according to the stabilisation parameters set in section 3.6.6.
Cancel button	Cancels the measurement. If a measurement analysis is in progress, then this data will be lost. Any measurement that have completed will be saved in the data logger.

Table 10: Measurement screen features

5.3.8 Step 8 - Measurement complete

After the analysis time has completed, the analyser determines and displays the Guided Measurement results together with a summary of the measurement settings as shown on Figure 45. If the "Alloy specification" option has been enabled in settings (section 5.2.7), then the specification limits are displayed and the final hydrogen measurement will appear in green if it is in specification or red if it is out of specification. If another measurement is required, then the analyser will show a progress bar for 20 seconds then perform the measurement. If all measurements have been completed, then the analyser will wait for up to 20 seconds then display a "Close" button in the top right corner of the screen. When the analysers displays the "Close" button it means that transfer of all Guided Measurement data to the data logger has been completed.

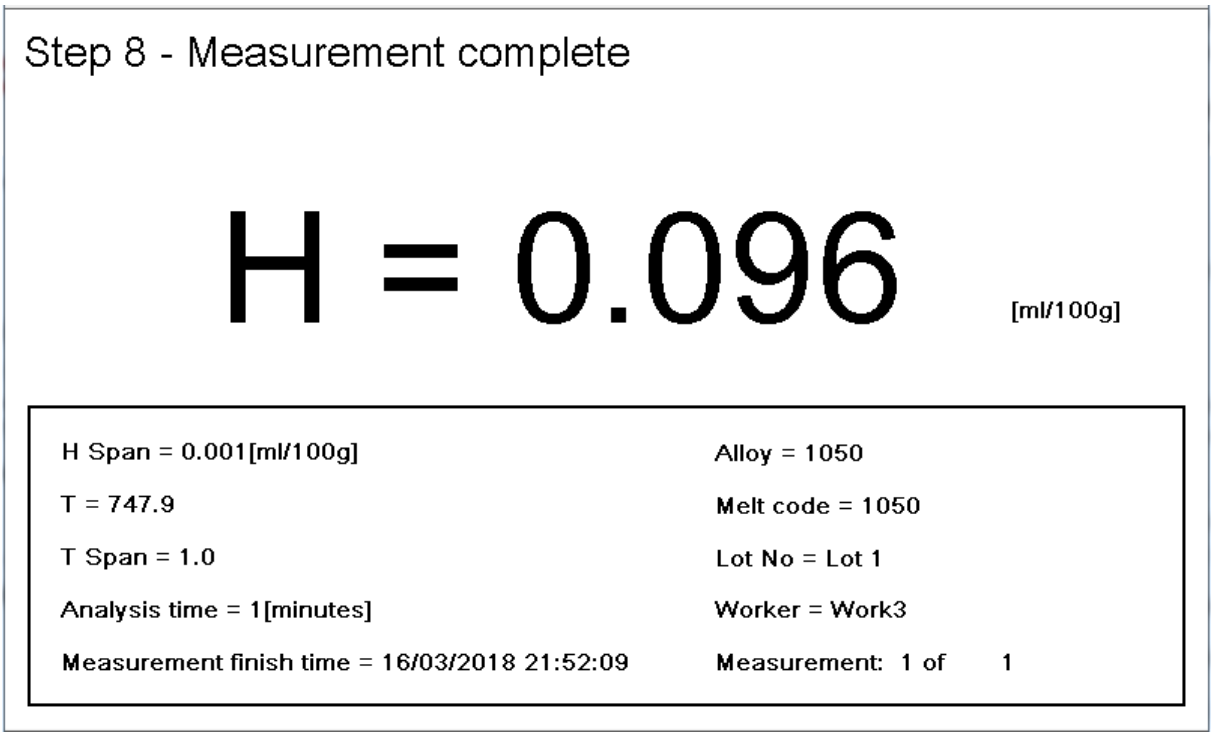


Figure 45: Measurement complete screen

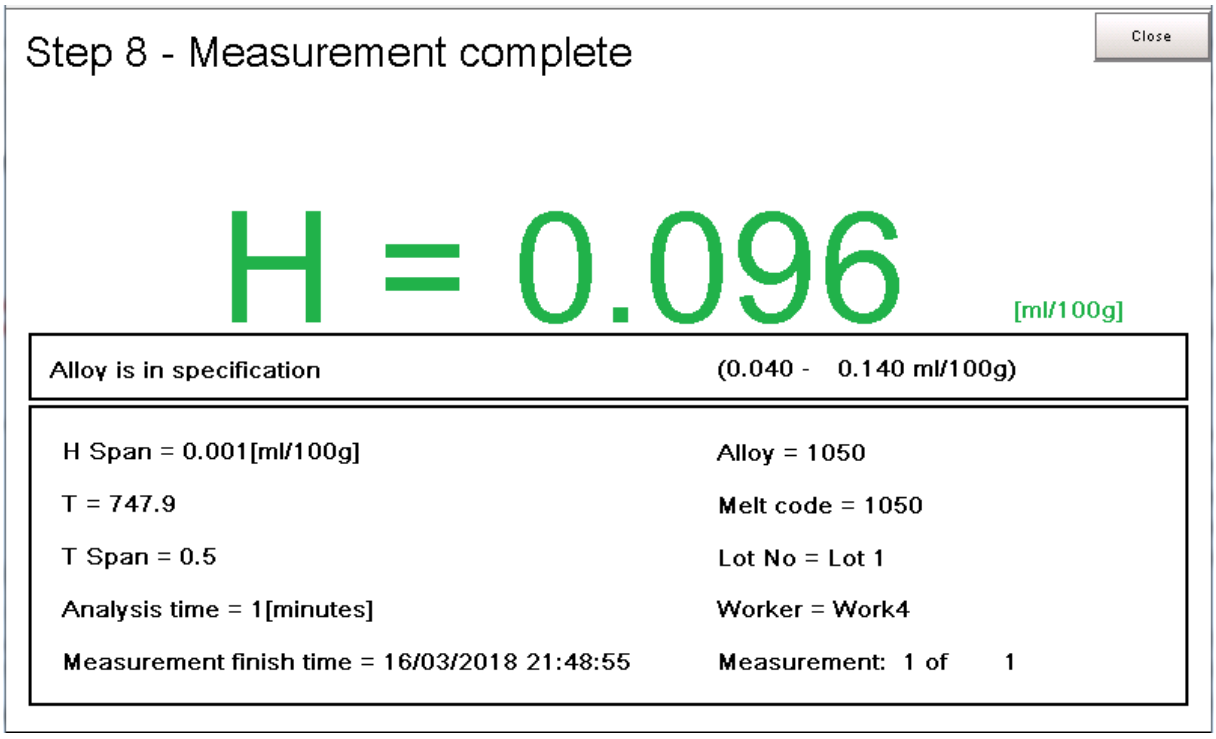


Figure 46: Measurement complete screen with alloy specification option enabled (in specification)

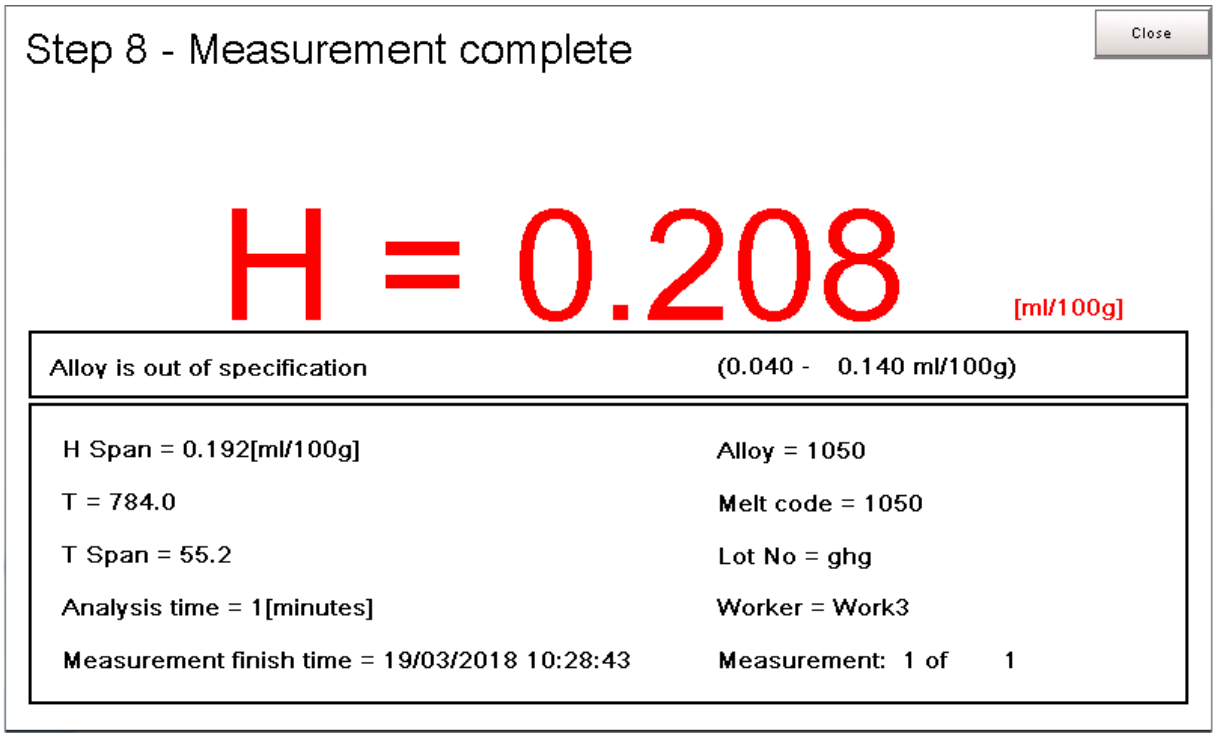


Figure 47: Measurement complete screen with alloy specification option enabled (out of specification)

5.3.9 Step 9 - Exit measurement

After the operator presses the "Close" button from Step 8, the analyser will start the gas purge and display the message "REMOVE PROBE NOW!". If measurements have finished then the probe should be removed, the analyser will automatically stop the gas purge when the probe temperature has cooled sufficiently. Alternatively, the user can leave the probe in the melt and press the "Cancel" button in the top right of the screen. All Guided Measurement data has been saved in the data logger at this point so will not be lost by pressing "Cancel".

5.4 Data archiving

A Guided Measurement may be located and viewed using the Hycal PC software as follows.

1. Import Hycal data into the PC software (section 9.4)
2. Click "Browse All"
3. Tick "Only show guided measurement results"
4. Locate the Melt Code entered in section 5.3.4 (step 4). Note that a time stamp is automatically added to the melt code.
5. The final Guided Measurement results will be displayed, See Figure 48.

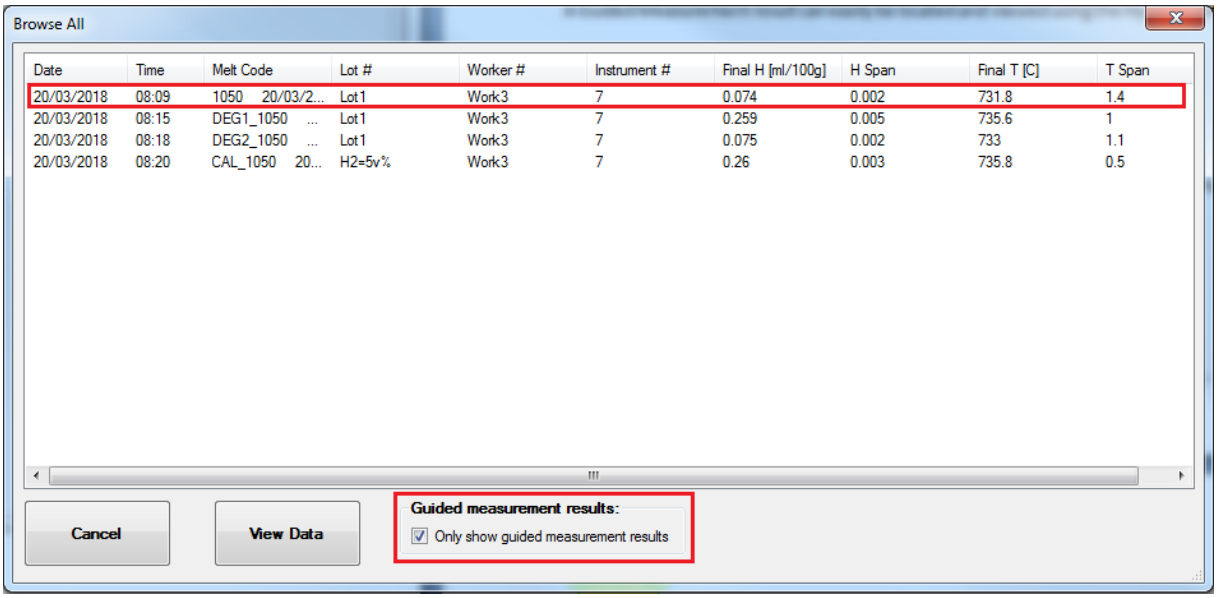


Figure 48: Guided Measurement data archiving

6 Hydrogen control

6.1 Background

Degassing of molten aluminium is commonly achieved by flushing the melt with a fine stream of inert gas bubbles using a Rotary Degassing Unit (RDU). The Hycal analyser is able to control hydrogen by monitoring the melt hydrogen level continuously during a degassing treatment. When the hydrogen level is at the required level, the Hycal sends a signal (relay contact closure) to the RDU to stop the degassing process. Controlling hydrogen in this manner improves quality control, reduces scrap and yields significant gas savings.

6.2 Alarm hardware options

The Hycal analyser is not fitted with hydrogen alarm hardware as standard. Two available options are:

1. Alarm socket

   A 2-pin alarm socket is fitted to the Hycal's electrical panel, connected to the Hycal' s internal alarm relay.

2. Wireless relay

   A wireless transmitter is fitted to the Hycal, antenna is fitted to the electrical panel. A wireless receiver relay mirrors the state of the Hycal's internal alarm relay.

6.3 Control strategy & parameters

Alarm behaviour is controlled by several parameters, these may be viewed and changed from the Settings screen (section 3.6.1):

- Alarm setpoint: S [ml/100g]
- Bounce threshold: T [ml/100g]
- Dwell time: X [seconds]

The "Bounce effect" is characterised by a small, rapid increase in hydrogen reading immediately after stopping the RDU, usually 0.02 - 0.03 ml/100g. The reading obtained whilst degassing is in fact artificially low by this amount, due to dilution of the melt with purge gas. When the purge gas has risen to the surface and left the melt, the true H level is measured. Consequently, in order to degas the melt to a level S, it is necessary to trigger the alarm at a level (S-T) where T is the bounce threshold.

Please refer to Figure 49 and Table 11. The alarm relay will activate if hydrogen is less than or equal to (S-T) for X seconds (relay will close). When hydrogen is greater than or equal to setpoint (S), the alarm will deactivate (relay will open)

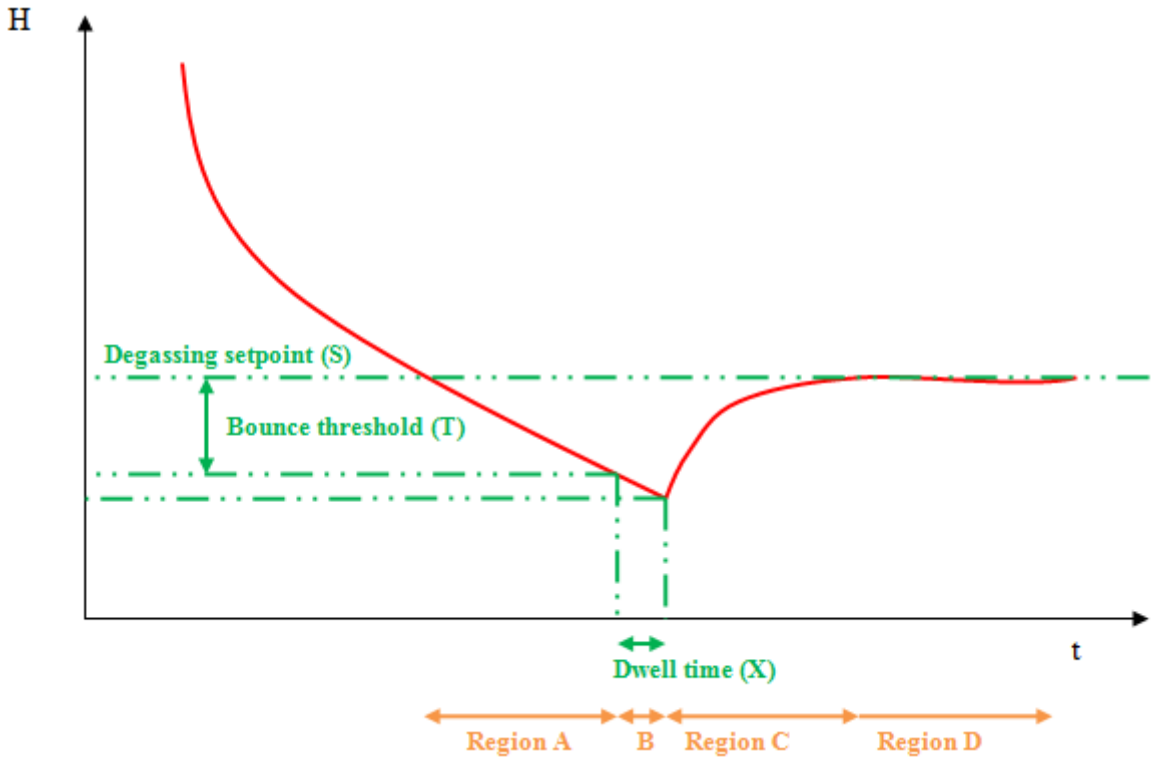


Figure 49: Hydrogen alarm strategy

Region	Alarm status	Detail
A	OFF	Hydrogen is less than the alarm setpoint, but alarm will not trigger until the level (S-T) to allow for the bounce effect.
B	OFF	Hydrogen level is now less than or equal to (S-T) but alarm will not trigger until this condition exists for X seconds. This strategy prevents a brief fluctuation, at any stage in the process, from triggering the alarm.
C	ON	Alarm triggers at the start of region C because hydrogen has been equal to or less than (S-T) for X seconds. Relay closure stops the degasser and hydrogen level immediately starts to rise due to the bounce effect. Alarm remains on until the hydrogen level rises above the setpoint.
D	OFF	When hydrogen level increases to a level greater than or equal to the setpoint (S), the alarm turns off.

Table 11: Hydrogen alarm behaviour

6.4 Guided Degassing mode

Guided Degassing mode guides the operator through the measurement setup procedure for a Hycal controlled melt degassing treatment. Similar to Guided Measurement, the Hycal first prompts the operator to enter all necessary information. It then monitors the degassing process until the desired melt hydrogen level is achieved, and at this point it send as signal to the RDU to stop degassing. It

also measured the hydrogen level before and after degassing. Data is automatically saved to the data logger.

6.4.1 Guided Degassing sequence

The Guided Degassing event sequence is shown on Figure 50.

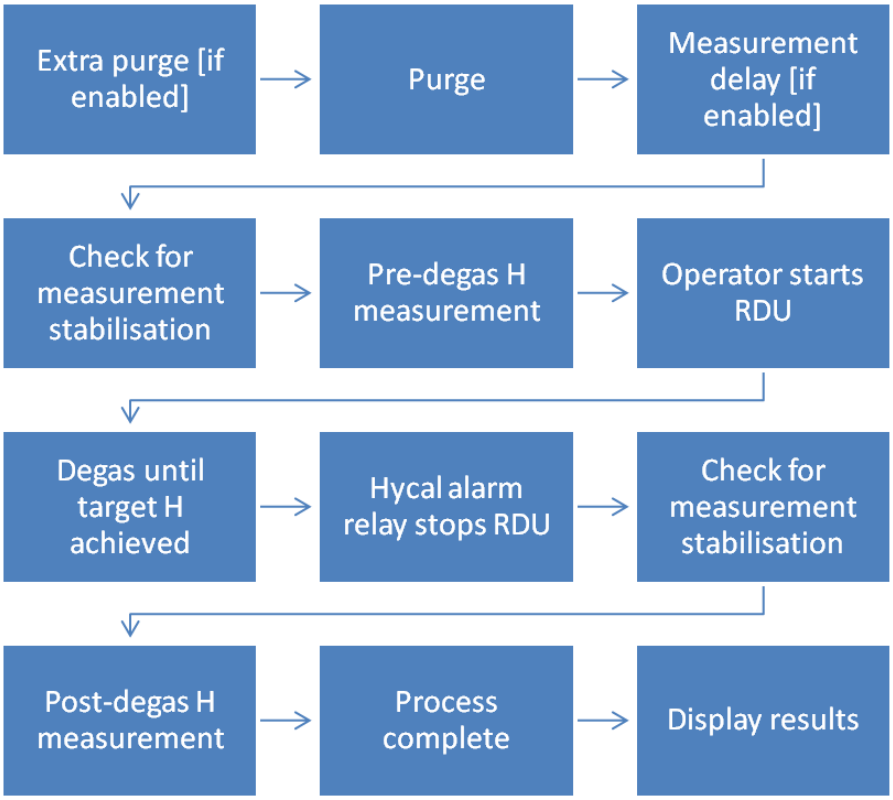


Figure 50:Guided Degassing event sequence

6.4.2 Guided Degassing settings

The Guided Degassing settings screen is located at Settings, Guided Degassing settings (section 3.6.8).

6.4.2.1 Guided Degassing ON/OFF

Default = ON. Turns Guided Degassing feature turned on or off. If Guided Degassing is off, then the "Start Guided Degassing" icon is removed from the "Measurement" screen and it is not possible to start a Guided Degassing measurement.

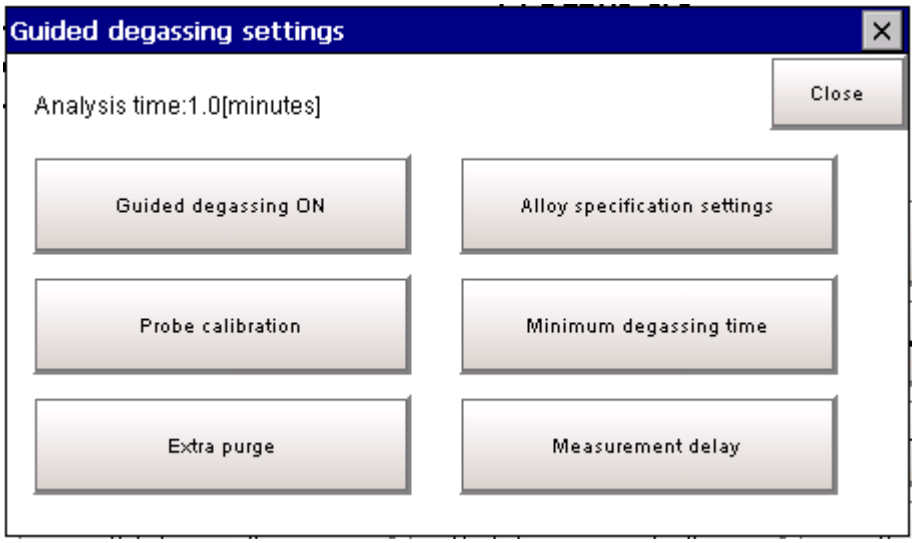


Figure 51: Guided degassing settings

6.4.2.2 Analysis time

Default = 1 minute. Sets the measurement analysis time for both pre and post-degassing hydrogen measurements.

6.4.2.3 Extra purge

See section 5.2.4.

6.4.2.4 Measurement delay

See section 5.2.5. Different measurement delay times may be specified before and after degassing.

6.4.2.5 Probe calibration

See section 5.2.6.

6.4.2.6 Alloy specification

See section 5.2.7.

6.4.2.7 Minimum degassing time

When enabled this setting disables the hydrogen alarm until the "minimum degassing time" has elapsed. This ensures that the melt will receive a degassing treatment for at least the length of time specified here, independent of the hydrogen level. This is to allow the degassing treatment sufficient time to remove inclusions, if the initial dissolved hydrogen content of the melt is low.

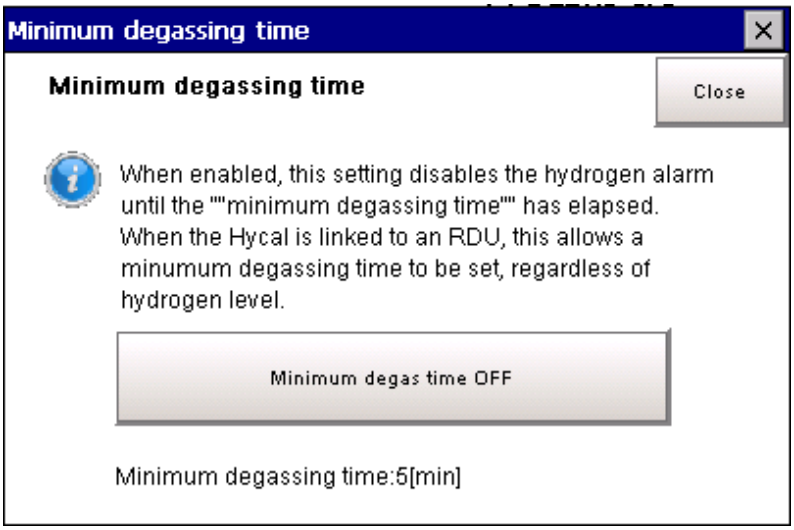


Figure 52:Minimum degassing time

6.4.3 Guided Degassing measurement steps

6.4.3.1 Step 1 - Step 5

These steps are identical to Guided Measurement, see sections 5.3.1 to 5.3.5.

6.4.3.2 Step 6 - Prepare for measurement

At this stage all the required information has been entered. The user can still press the Back button and make corrections if necessary. The messages displayed will depend on the probe status as shown on Table 9. This screen also shows the alarm settings. If the user is logged in as "Engineering" then the settings may be adjusted if necessary.

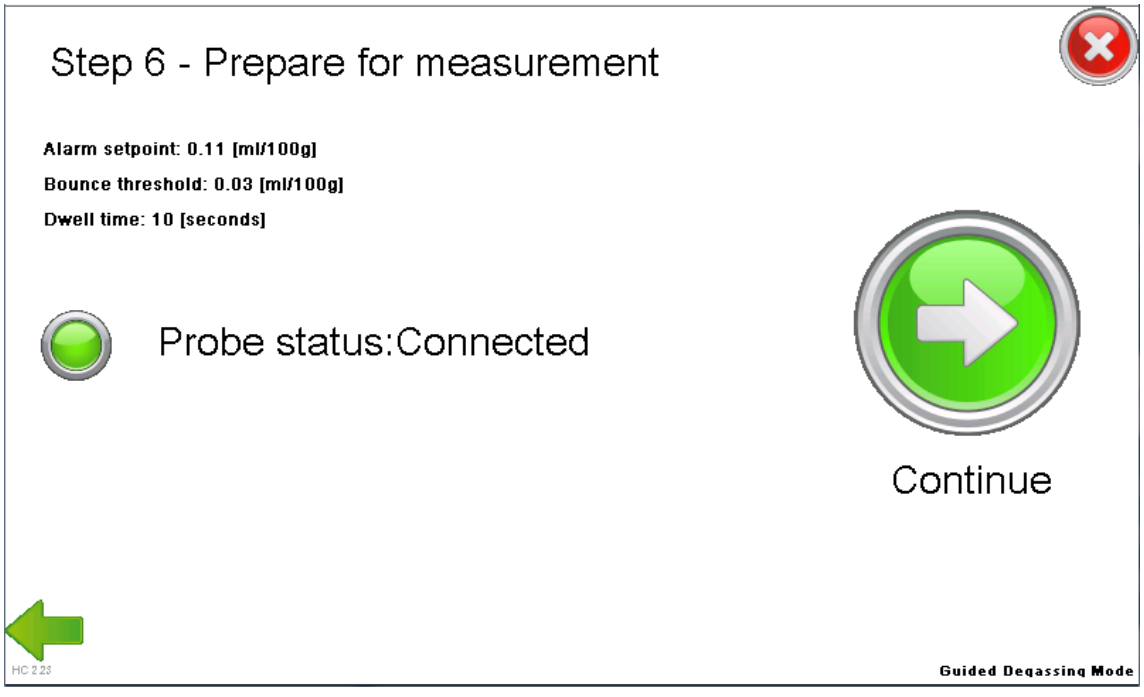


Figure 53: Prepare for measurement

6.4.3.3 Step 7 - Degassing treatment

After all measurement data has been entered, the Hycal will measure the hydrogen level before degassing and will then prompt the operator to start the RDU. The operator must press the Hycal screen to confirm that the RDU has started (Figure 54).

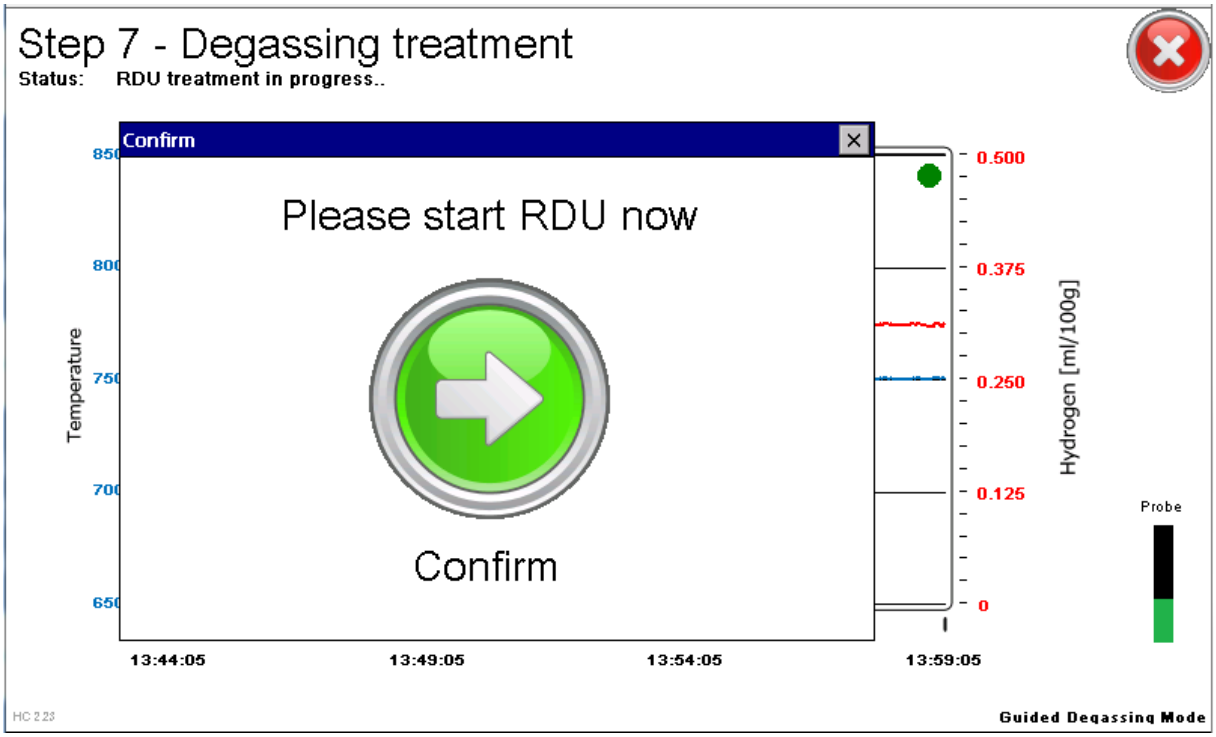


Figure 54: Guided Degassing treatment

After the operator has confirmed that the RDU has started, the Hycal will measure continuously and trigger the alarm when the hydrogen level is sufficiently low. When the alarm is active, a yellow light bulb indicator appears in the top right of the screen, see Figure 55. The Hycal will then check for measurement stabilisation before performing the post-degassing hydrogen measurement.

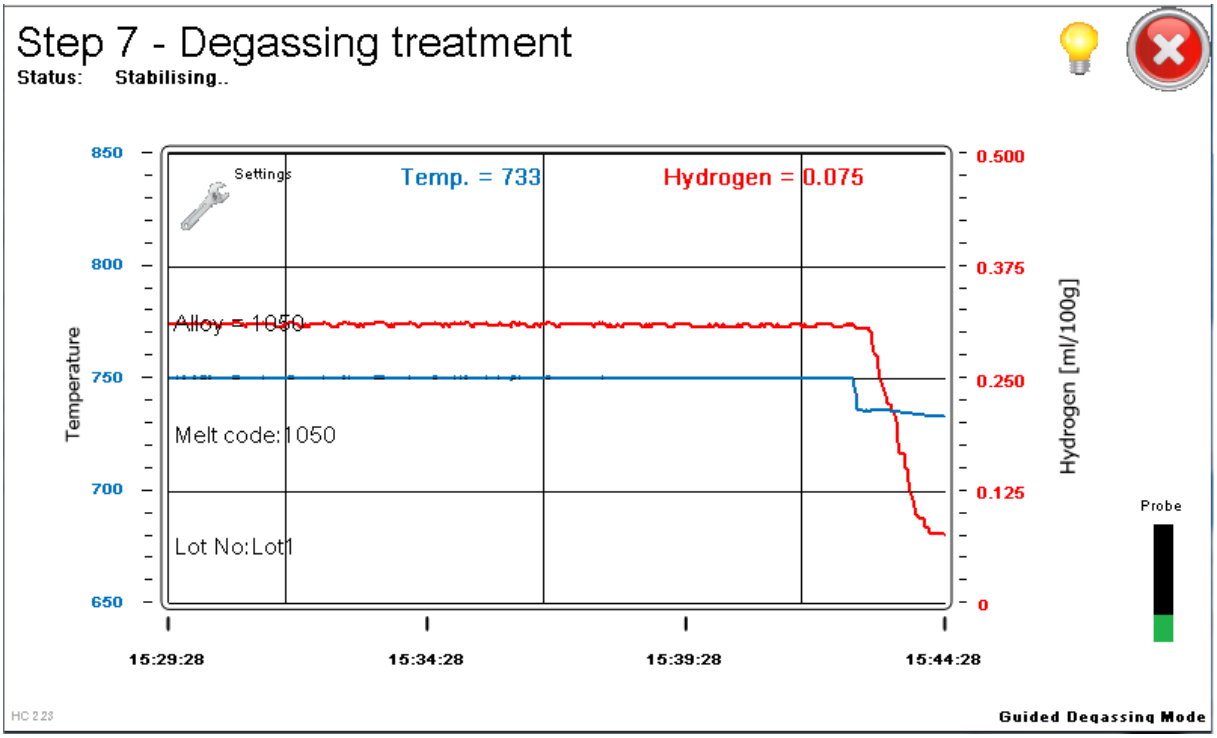


Figure 55: Guided Degassing alarm active

6.4.3.4 Step 8 - Measurement complete

After the post-degassing measurement analysis time has completed, the analyser determines and displays the Guided Degassing results together with a summary of the measurement settings as shown on Figure 56. If the "Alloy specification" option has been enabled in settings (section 6.4.2.6), then the specification limits are displayed and the final hydrogen measurement will appear in green if it is in specification or red if it is out of specification. When the analysers displays the "Close" button it means that transfer of all Guided Degassing data to the data logger has been completed.

6.4.3.5 Step 9 - Exit measurement

After the operator presses the "Close" button from Step 8, the analyser will start the gas purge and display the message "REMOVE PROBE NOW!". If measurements have finished then the probe should be removed, the analyser will automatically stop the gas purge when the probe temperature has cooled sufficiently. Alternatively, the user can leave the probe in the melt and press the "Cancel" button in the top right of the screen. All Guided Degassing data has been saved in the data logger at this point so will not be lost by pressing "Cancel".

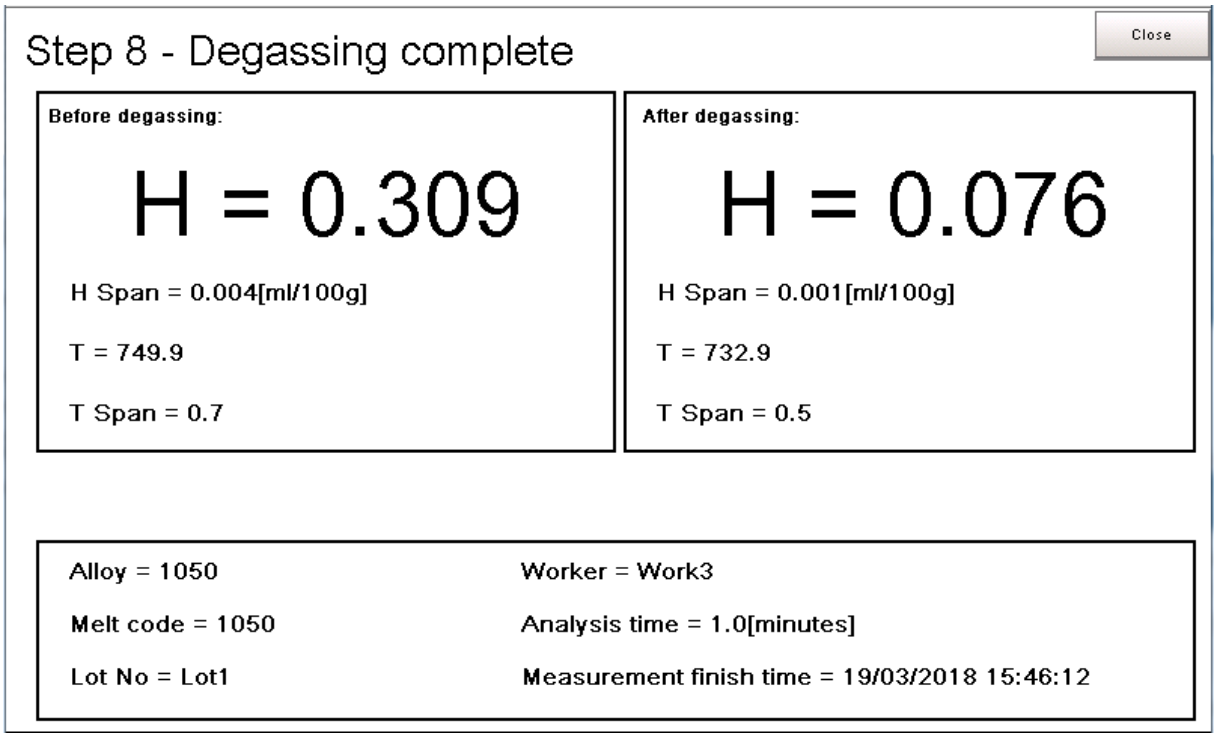


Figure 56: Guided Degassing measurement complete

6.4.4 Data archiving

Guided Degassing results may be located and viewed using the Hycal PC software as follows.

1. Import Hycal data into the PC software (section 9.4)
2. Click "Browse All"
3. Tick "Only show guided measurement results"
4. Locate the Melt Code entered in section 5.3.4 (step 4). Note that there are 2 measurements associated with a Guided Degassing measurement; one before and one after degassing. The melt code has a prefix "DEG1_" for the pre-degassing measurement and "DEG2_" for the post-degassing measurement (see Figure 57).
5. The final Guided Degassing results will be displayed.

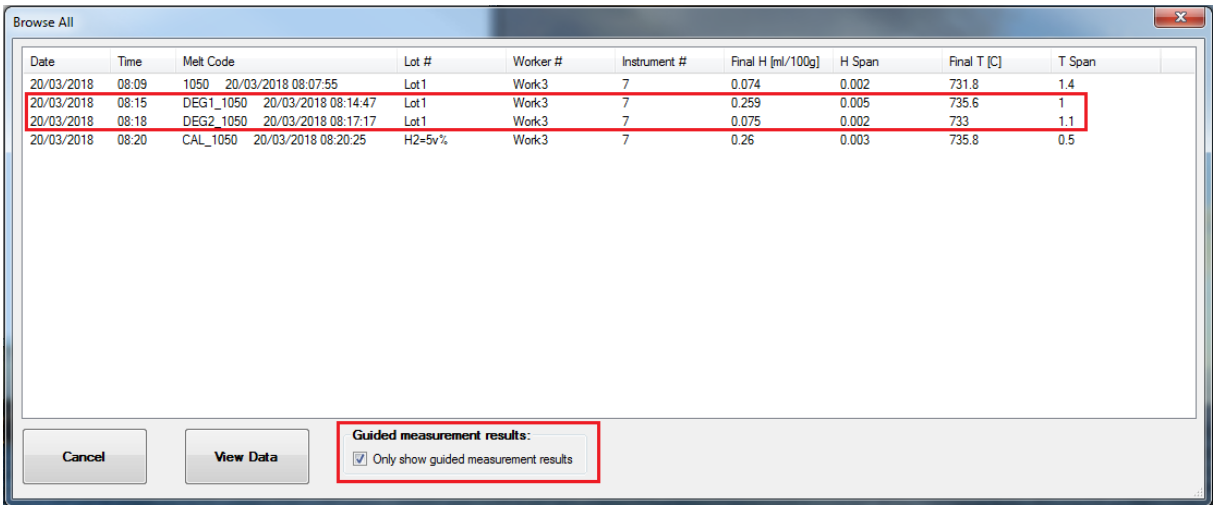


Figure 57: Guided Calibration data archiving

7 Guided Calibration

Hycal measurement precision is ensured through a purge system which prevents blockage and oxide build up. The gas system may also be used to perform an in-situ calibration check of the Hycal probe, by purging the probe with a calibration gas of known hydrogen concentration. Guided Calibration mode guides the operator through the calibration procedure, conducts a calibration test, then displays a pass / fail test result.

7.1 Guided Calibration sequence

The Guided Calibration event sequence is shown on Figure 58.

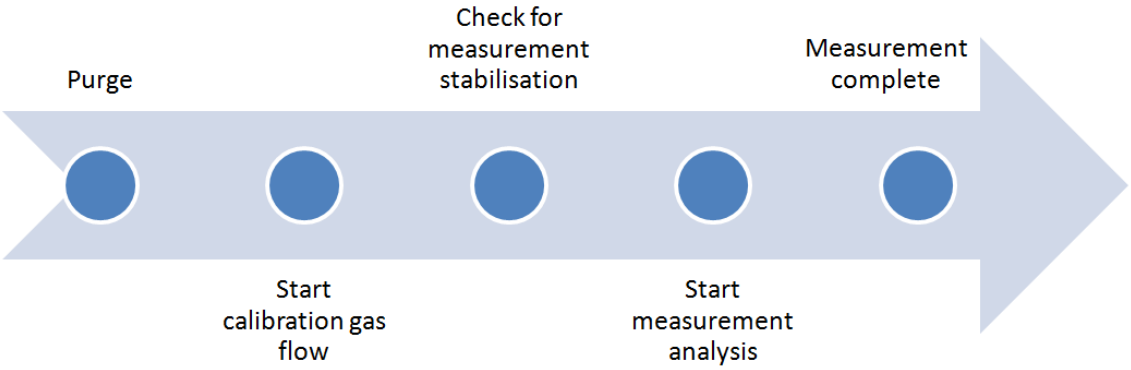


Figure 58: Guided Calibration event sequence

7.2 Guided Calibration settings

The Guided Measurement settings screen is located at Settings, Guided Calibration settings (section 3.6.5).

7.2.1 Guided Calibration ON / OFF

Default = ON. Turns the Guided Calibration feature turned on or off. If Guided Calibration is off, then the "Start Guided Calibration" icon is removed from the "Measurement" screen and it is not possible to start a Guided Calibration.

7.2.2 Calibration tolerance

The calibration procedure involves purging the Hycal probe with a gas of known hydrogen concentration. For a given alloy at the measurement temperature, this corresponds to a theoretical dissolved hydrogen level. For example, if alloy LM25 at 750C is purged with a gas mixture of 5% H2 in an inert carrier (argon or nitrogen), this corresponds to a dissolved hydrogen level of 0.254 ml/100g. The "calibration tolerance" is the acceptable measurement variation (percent) above and below this nominal hydrogen value. For example, if the calibration tolerance is set to +/-10% then for a theoretical hydrogen concentration of 0.254 ml/100g the acceptable measured hydrogen level is 0.227 - 0.279 ml/100g.

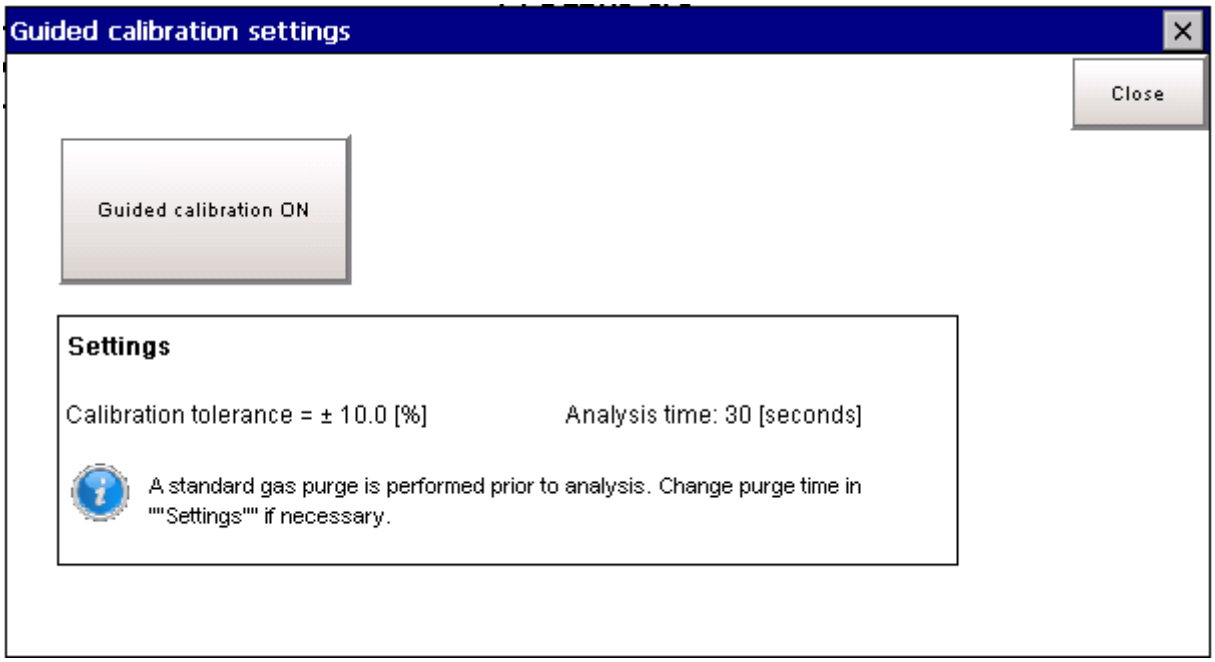


Figure 59: Guided Calibration setting

7.2.3 Analysis time

Default = 30 seconds. Sets the measurement analysis time.

7.2.4 Purge time

A standard purge is performed prior to the analysis. Change the purge time in Settings (section 3.6) if necessary.

7.3 Calibration gas supply

The Hycal analyser must be supplied with hydrogen calibration gas of known concentration. This can be achieved either by filling the internal cylinder with calibration gas or feeding the low-pressure inlet with calibration gas.

7.3.1 Internal cylinder

1. Empty the internal cylinder (section 2.5)
2. Fill the internal cylinder with calibration gas (section 2.2)
3. Ensure that the Hycal is set to "HP cylinder"
4. Set the purge time to 30 seconds
5. At room temperature (probe not immersed in the melt), connect the probe to the Hycal and press the purge button

7.3.2 Low pressure inlet

1. Connect the Hycal's low pressure inlet to the calibration gas cylinder
2. Set the calibration gas cylinder regulator to between 3 and 4 bar
3. Ensure that the Hycal is set to "LP inlet"
4. Set the purge time to 2 minutes
5. At room temperature (probe not immersed in the melt), connect the probe to the Hycal and press the purge button
6. Set the purge time to the value required for the calibration procedure e.g. 30 seconds.

7.4 Guided Calibration steps

7.4.1 Step 1 - Step 3

These steps are identical to Guided Measurement, see sections 5.3.1 to 5.3.4.

7.4.2 Step 4 - Enter calibration gas composition

Enter the vol.% of hydrogen in the calibration gas.

7.4.3 Step 5 - Check probe calibration

Check that the probe details are correct and change them if necessary by pressing the relevant field and entering the required information.

7.4.4 Step 6 - Prepare for measurement

At this stage all the required information has been entered. The user can still press the Back button and make corrections if necessary. The messages displayed will depend on the probe status as shown on Table 9.

7.4.5 Step 7 - Measurement

After performing a purge, the Hycal will deliver the calibration gas to the probe at low pressure and display the theoretical hydrogen level on the measurement screen (Figure 60). After detecting measurement stabilisation, the results will be measured and analysed.

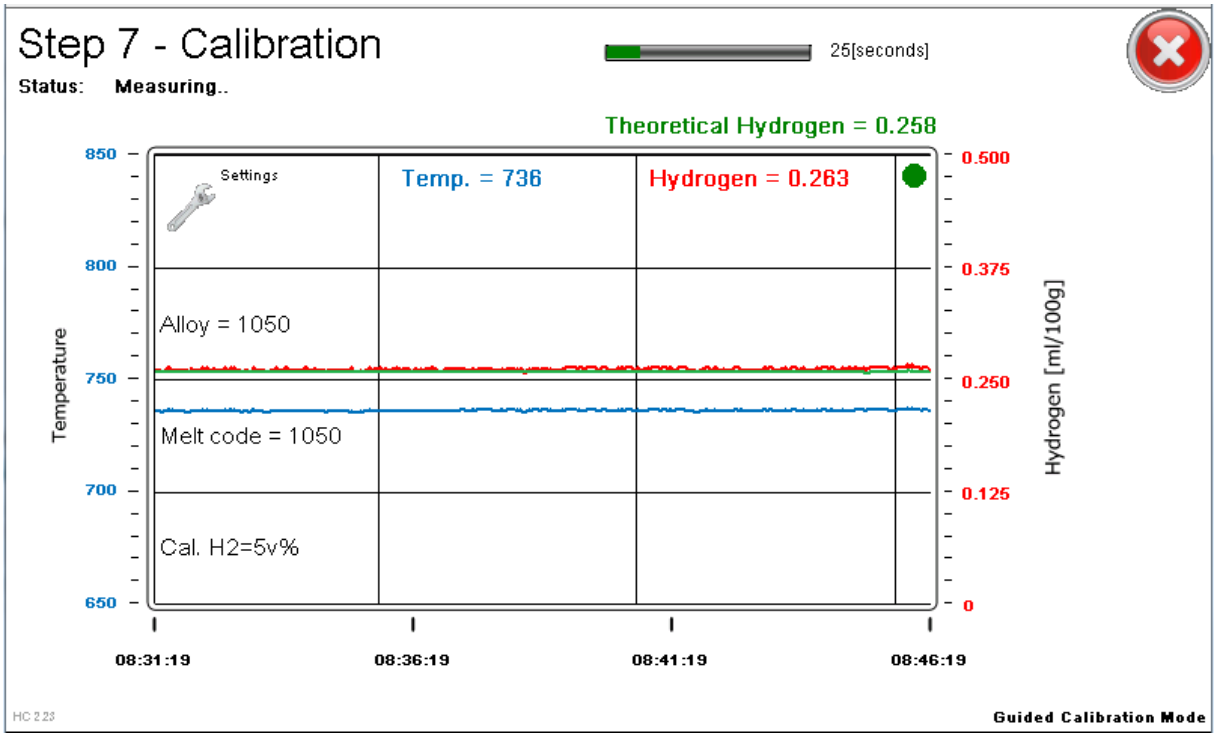


Figure 60: Guided Calibration measurement

7.4.6 Step 8 - Measurement complete

The Hycal calculates the Guided Calibration results and displays them as shown on Figure 61. After all data has been saved by the data logger, the "Close" button will appear in the top right of the screen.

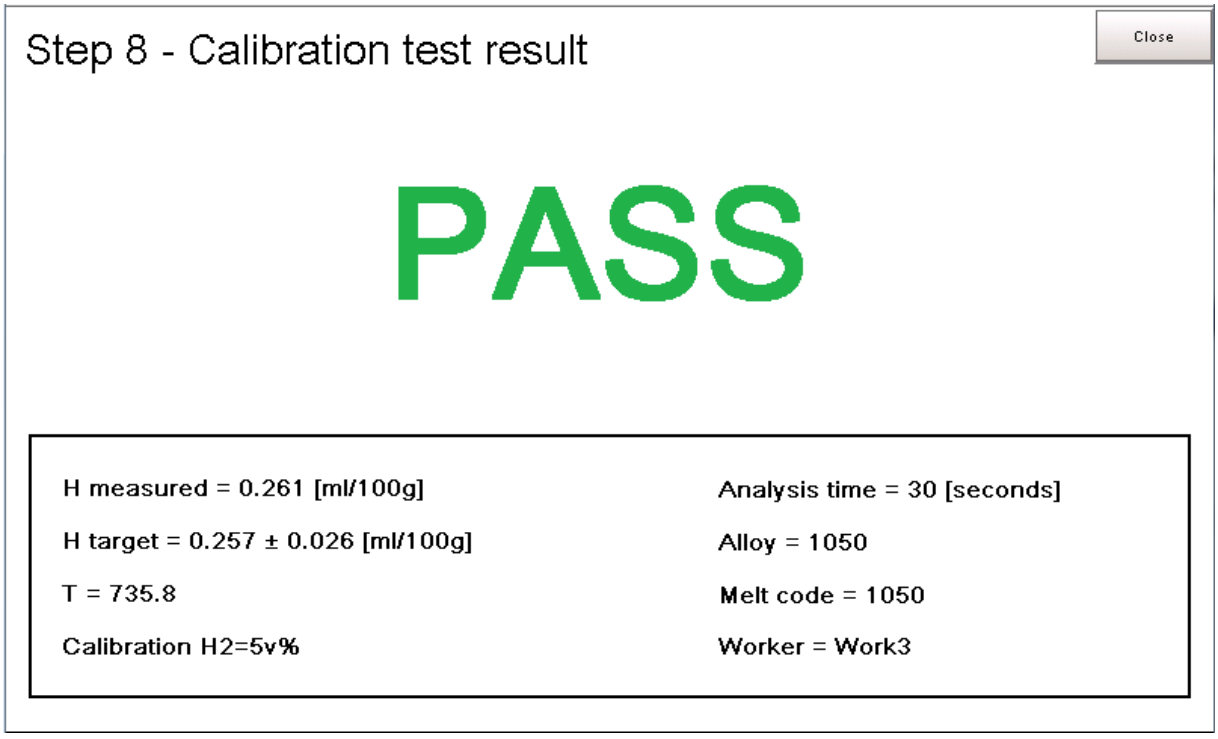


Figure 61: Guided Calibration test result

7.4.7 Step 9 - Exit measurement

After the operator presses the "Close" button from Step 8, the analyser will start the gas purge and display the message "REMOVE PROBE NOW!". If measurements have finished then the probe should be removed, the analyser will automatically stop the gas purge when the probe temperature has cooled sufficiently. Alternatively, the user can leave the probe in the melt and press the "Cancel" button in the top right of the screen. All Guided Calibration data has been saved in the data logger at this point so will not be lost by pressing "Cancel".

7.5 Data archiving

Guided Calibration results may be located and viewed using the Hycal PC software as follows.

1. Import Hycal data into the PC software (section 9.4)
2. Click "Browse All"
3. Tick "Only show guided measurement results"
4. Locate the Melt Code entered in section 5.3.4 (step 4). The melt code has a prefix "CAL_"
5. The final Guided Calibration results will be displayed, see Figure 62.

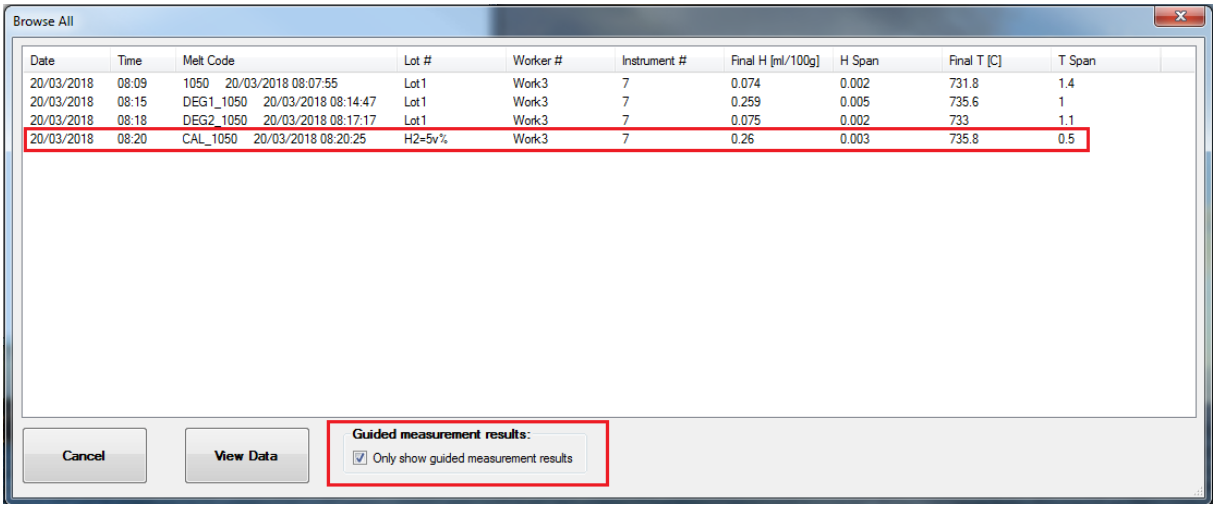


Figure 62: Guided Calibration data archiving

8 Service & Maintenance

8.1 Touch screen recalibration

If a touch screen recalibration is necessary, first enter the Service menu then perform the recalibration as detailed below.

8.1.1 Service menu

To enter the service menu, proceed as follows:

1. Power off the Hycal analyser
2. Press down on the touch screen. Do not release
3. Turn on the Hycal analyser
4. Keep pressing down on the touch screen until prompted for the Service menu password (this takes approximately 30 seconds).
5. Enter the service menu password: 100
6. Press once on the touch screen to show the Service Menu

8.1.2 Touch screen recalibration

Select "Touch Calibrate" and follow the on-screen instructions to perform the calibration. When complete, touch the screen again to return to the Service Menu. To finish, switch the Hycal analyser off then back on again.

8.2 Software / firmware upgrade

There are two types of upgrade associated with the Hycal analyser:

(i) Display software controls the functionality of the touch screen panel

(ii) DAQ firmware controls the functionality of the internal Data Acquisition Unit (DAQ)

To view currently installed software / firmware versions, log in as "Engineering" then navigate to the "Settings" screen (Figure 13). Current versions are shown in the top left of the screen. Software / firmware upgrades are provided by email or by download.

8.2.1 Upgrade display software

To upgrade the display software, proceed as follows:

1. The software upgrade will re-set a number of analyser presets to their default values. Prior to performing the upgrade, check Table 12 and record any important settings if necessary.
2. If the software upgrade has been provided by email or by download, then it will be contained in a compressed zip archive. Open the archive, and any subfolders then extract the contents to the root directory of a FAT32 formatted USB stick. After doing this, the root directory of the USB stick should contain 3 folders and 14 files as shown on Figure 63.

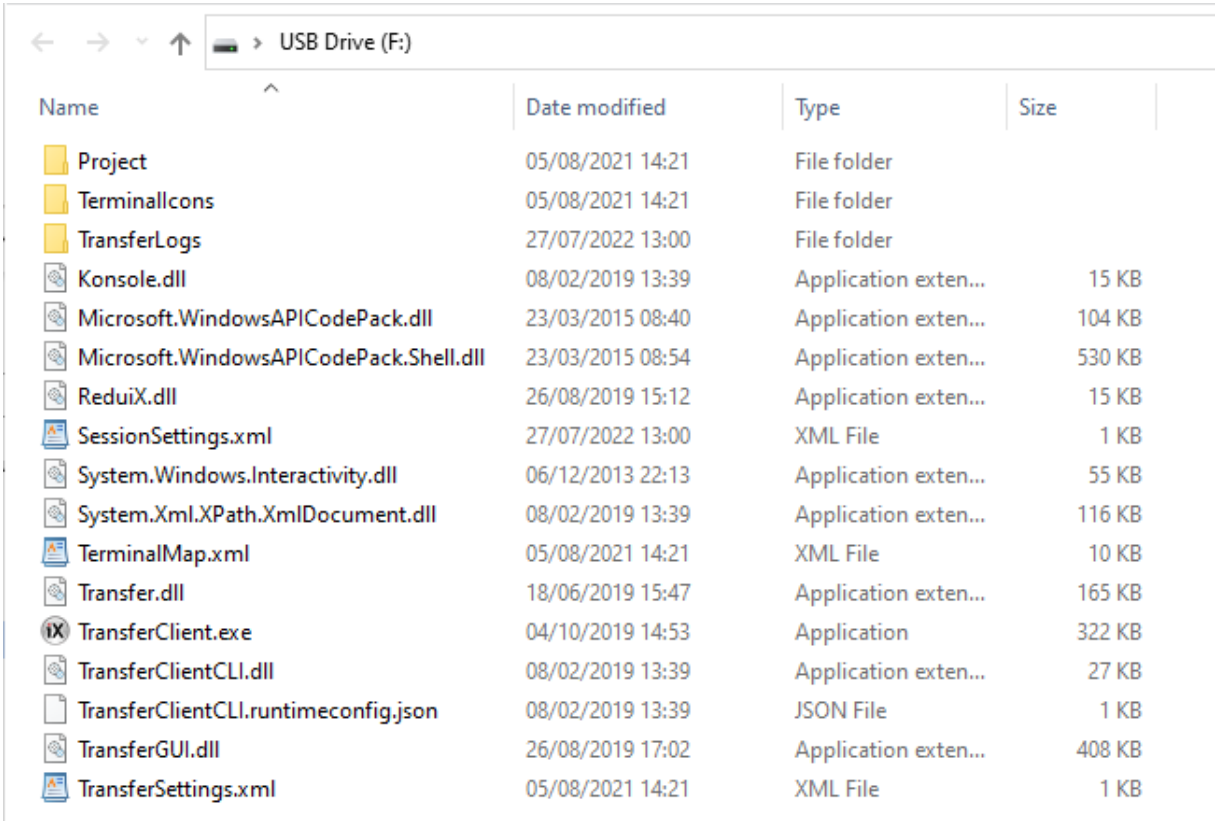
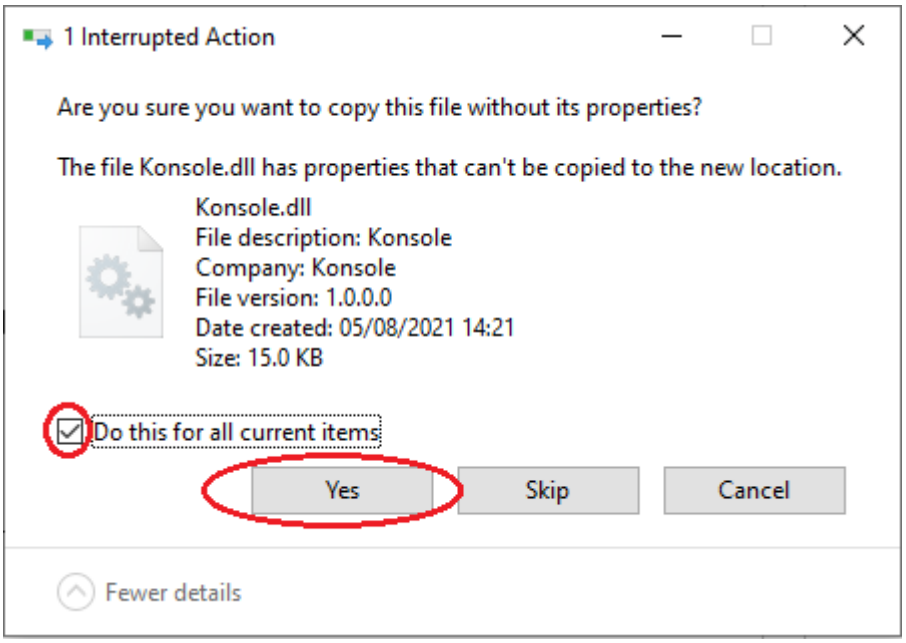


Figure 63: Software folder

3. The PC will ask "Are you sure you want to copy this folder [or file] without its properties?", tick "Do this for all current items" then "Yes" (see Figure 64).



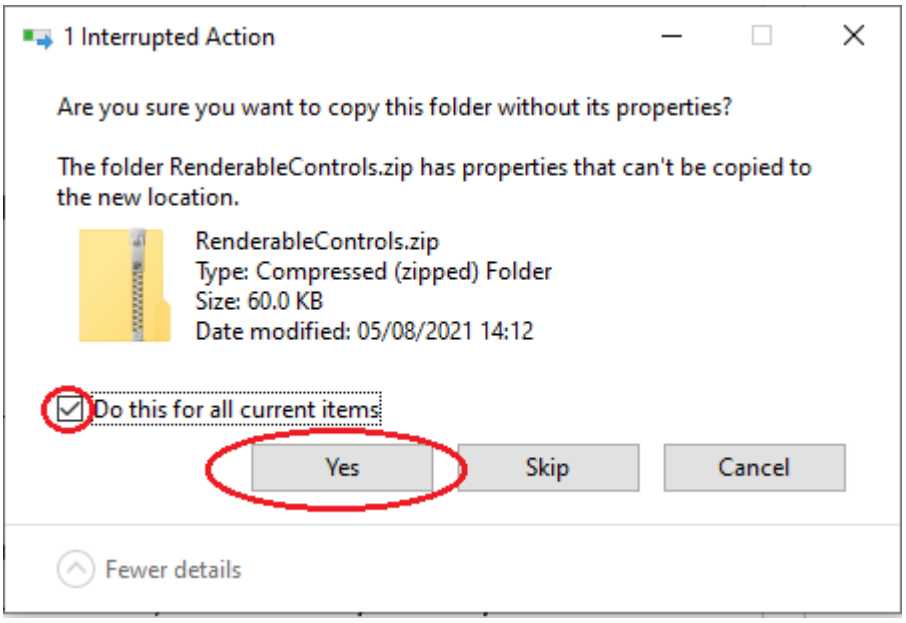


Figure 64: Folder / file properties warning message

4. Wait for all the files to copy to the USB stick then remove the stick from the PC
5. Ensure Hycal screen saver is not active:
    a. Turn the Hycal on and allow it to fully start
    b. Press on the screen to ensure that the screen saver is off
    c. Wait 30 seconds
    d. Turn the Hycal off
6. Put the USB stick into the Hycal's external USB port (next to the Ethernet port)
7. Turn the Hycal on
8. If necessary, enter the service menu password (100)
9. When asked "Copy project from USB memory?" press “Yes”
10. When asked "Backup existing project?" press “No”
11. Wait for Hycal to start up
12. Re-enter any pre-sets recorded in step 1
13. Remove USB stick, delete files from step 2

Parameter	Detail
Language Set	No
Chart scale	Reset

Guided Measurement	ON
SensorZ700	8
SensorZ750	5
Guided Measurement Analysis Time	1 minute
Extra purge	OFF
Extra purge time	60 seconds
Extra purge wait time	60 seconds
Alloy selected	Not defined, must select an alloy
Calibration analysis time	30 seconds
Calibration tolerance	10%
Calibration purge time	30 seconds
Calibration pH2	0.1%
Security setting defaults	
Engineering password	100
Manager password	001
Operator	010

Table 12: Parameter defaults after software update

8.2.2 Upgrade DAQ firmware

The Hycal analyser comprises a display unit, which provides the user interface, and a data acquisition unit (DAQ) which interfaces with the probe and internal hardware. Should a firmware upgrade of the DAQ be required, proceed as follows:

9. EMC personnel will provide a firmware upgrade file "firmware.daq" by email or otherwise. Copy this file onto the root directory of a USB memory stick
10. Open the gas service panel (Figure 5).
11. Insert the USB memory stick into the port labelled "USB SERVICE"
12. Log in as Engineering, navigate to the "Settings" menu then make a note of the current firmware version in the top left hand corner (see Figure 13) then press "Upgrade firmware".
13. Press the "Press to upgrade firmware" button. The Hycal analyser will turn off, apply the upgrade, then restart. This process can take several minutes.
14. When the upgrade is completed, log in as Engineering, navigate to "Settings" and verify that the firmware version from step 12 has now been upgraded.

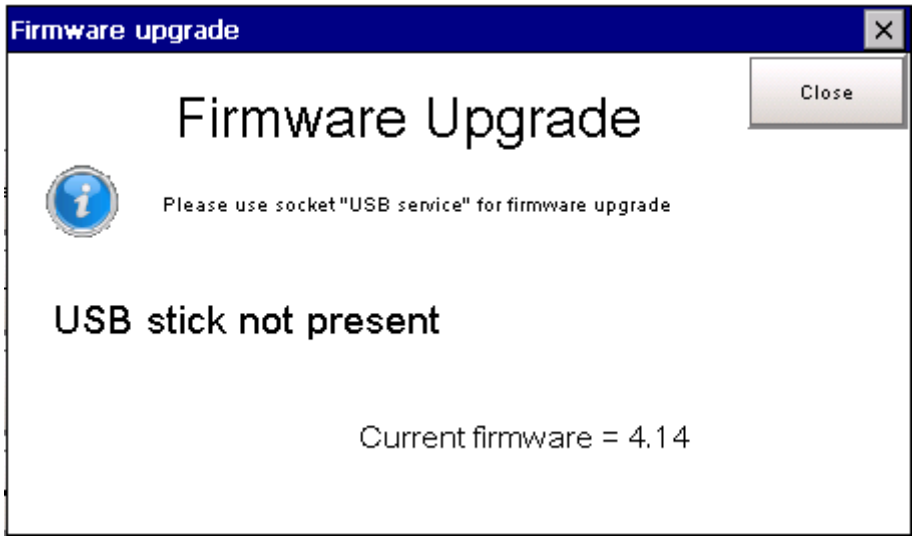


Figure 65: Upgrade DAQ firmware screen

8.3 Calibration

Certified calibration of the Hycal analyser, traceable to international standards, is conducted at EMC's factory in the UK or at a worldwide EMC authorised service location. The calibration involves checking the analyser's sensor measurement input and thermocouple input against signals provided by a calibrated voltage source and thermocouple simulator. Adjustments are made if necessary. Functional checks are also performed on all other analyser features such gas purge, pressure measurement, and flow rate.

The Hycal analyser is supplied with a calibration certificate valid for 12 months, EMC recommends that calibration is performed every 12 months.

9 PC software

The Hycal analyser is supplied with a PC software suite with the following features:

1. Archiving of analyser data into a PC database
2. Viewing, and printing of data in chart format and spreadsheet format
3. Remote viewer for remote viewing and control of the Hycal analyser over Ethernet

The Hycal data file is in an unprotected CSV format so, in addition to importing to the PC software, the data file may be opened directly by a spreadsheet program e.g. Excel. Each row of data contains a validation code that is checked by the PC software on import to prevent unauthorised data modification.

9.1 Setup

9.1.1 Requirements

The Hycal PC software requires a PC running Windows 7, Windows 8, or Windows 8.1 (32 bit or 64 bit).

9.1.2 Installation

1. Ensure the PC user is logged on as Administrator
2. Run the installer provided by EMC Limited
3. Follow the instructions provided by the installation wizard

9.1.3 Activation

The PC software must be activated before use. When run the software checks whether or not it has been activated. If not, it will provide a software ID code and will request an unlock code. Email the ID code to you EMC representative, they will email back an unlock code. Enter the unlock code and the PC software will run. This procedure only needs to be done once per installation.

9.1.4 Firewall ports

The following firewall ports must be open to allow proper communication with the Hycal analyser over Ethernet.

Port	Detail
20	FTP ports required for transfer of data log file
21	
502	Modbus TCP port required for remote triggering of data log file export
5900	Port for VNC remote viewer

Table 13: Firewall ports

9.2 Home screen

The Hycal PC software Home screen provides a series of quick link icons to perform common tasks relating to data transfer, finding data, and the remote viewer.

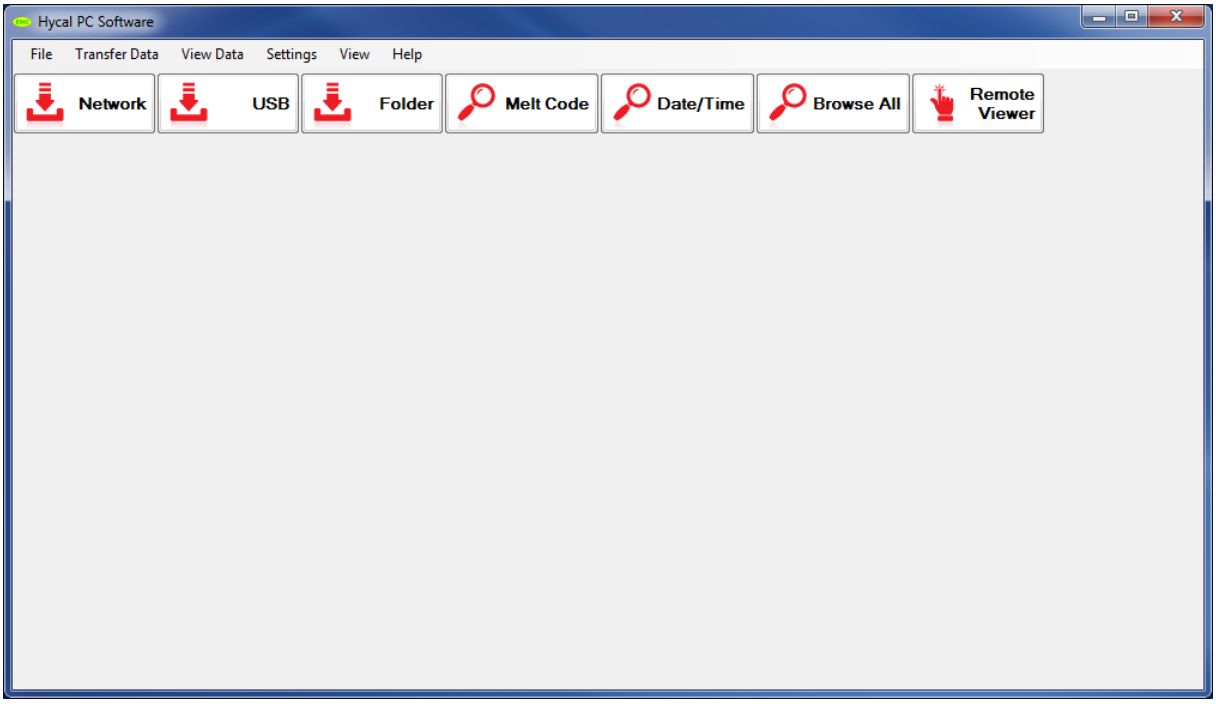


Figure 66: Home screen

9.3 Database management

9.3.1 Location

A default location for the Hycal database file is chosen during installation but this may be changed to any location on the current hard disc, an external hard disc, or a network location. Click "Settings", "Database", "Database Location" to set the database location. If data is already recorded the existing database file will be moved to the new location specified.

9.3.2 Export / Import

The database file may be exported / imported e.g. when transferring to a different PC. Click "Settings", "Database", select "Export Database" or "Import Database" as required, then select a file location.

9.4 Transferring data

9.4.1 Import time

Transferring data from the Hycal to the PC takes approximately 20 seconds per hour of data logged. Therefore, if the Hycal is left recording for a full 8 hour shift this will take just under 3 minutes to import in to the PC software. If the Hycal's memory is completely full (125 hours = 5.2 days of continuous data) this will take just under 45 minutes to import.

9.4.2 Network

1. Ensure that the Hycal analyser is connected to an Ethernet network, that its IP address is known (see section 3.6.3 for instructions to set the Hycal IP address), and that the firewall ports in Table 13 are open.
2. On the PC software press "Network"
3. Enter the details as prompted then press Start:
    a. Hycal IP address
    b. Username = Engineering
    c. Password = 100
4. The PC software will trigger data log file export on the Hycal analyser, copy the log file, then transfer the log entries into the PC database.

9.4.3 USB

1. Export the Hycal's data log file to USB memory stick as detailed in section 3.9.1.2.1.
2. Insert the USB stick into the PC then click "USB" on the PC software
3. The software will scan for USB sticks and automatically import the log file into the PC database

9.4.4 Folder

The HycalLog.csv data file may be imported directly (e.g. if it has been emailed) as follows:

1. Click "Folder" on the PC software
2. Browse to the HycalLog.cdv file location
3. Click "Open"
4. The software will import the log file into the PC database

9.5 Locating data

Whenever the user enters a melt code into the Hycal analyser, the analyser generates a new time stamped melt code. These time stamped melt codes are used to identify data sets in the PC software.

Data may be located by searching for a particular melt code, date and time, or all data may be viewed using the Browse all option. In all cases, the result(s) displayed in the search box correspond to the first reading of a new melt code.

There are two types of data:

1. "Normal data" is data collected when manually starting / stopping the data logger, resulting in sets of data logged at 10 second intervals.

2. "Guided Measurement data" are final readings logged automatically by the Hycal analyser on completion of a Guided Measurement cycle. See section 0 for more details about Guided Measurement mode.

9.5.1 Guided Measurement data

All three search options (melt code, date and time, browse all) share the same options for displaying or hiding Guided Measurement data. One of 3 radio buttons are selected by the user as detailed on Table 14.

Guided Measurement results radio button	Detail
Hide final readings	Guided Measurement data is removed. Only normal data is shown in the search results and when viewing data.
Show final readings	Normal data and Guided Measurement data are shown in the search results and when viewing the data. This is how the data appears in the Hycal analyser's data file.
Show final readings only	Normal data is removed. Only Guided Measurement data is shown in the search results and when viewing the data. This option is recommended for viewing Guided Measurement data because it displays the final Guided Measurement readings directly in the search results box. *Note: It is necessary to resize (make wider) the search results window, or use the horizontal scroll bar, to see the Guided Measurement results in the search box.*

Table 14: Search and display of Guided Measurement data

9.5.2 Melt code search

1. Click the "Melt Code" search button
2. Select a search option:
    a. Exact match: Finds the exact melt code entered into the search box
    b. Broad match: Finds any melt codes containing the alpha numeric character sequence entered into the search box
    c. All melt codes: Finds all melt codes in the database
3. Select the required Guided Measurement display option using the radio buttons, according to Table 14.
4. Click search. A list of matching melt codes will be displayed with the following data from when the melt code was started: Date / time, Lot No., Worker, Instrument No. If necessary, use the vertical scroll bar to reveal more results.
5. Click on the desired melt code then click "View Data"
6. This will show the data corresponding to the selected melt code on the chart view

9.5.3 Date / Time search

1. Click the "Date / Time" search button
2. Select a specific date using the drop-down menus for day, month, year.
3. Select the required Guided Measurement display option using the radio buttons, according to Table 14.
4. Click search. A list of matching melt codes will be displayed for the selected day in chronological order, with the following data from when the melt code was started: Date / time, Lot No., Worker, Instrument No. If necessary, use the vertical scroll bar to reveal more results.
5. Click on the desired melt code then click "View Data"
6. This will show the data corresponding to the selected melt code on the chart view

9.5.4 Browse all

1. Click the "Browse all" button
2. A list of all melt codes will be displayed for the selected day in chronological order, with the following data from when the melt code was started: Date / time, Lot No., Worker, Instrument No. If necessary, use the vertical scroll bar to reveal more results.
3. Select the required Guided Measurement display option using the radio buttons, according to Table 14, to filter the Guided Measurement data.
4. Click on the desired melt code then click "View Data"
5. This will show the data corresponding to the selected melt code on the chart view

9.6 Viewing data

9.6.1 Chart view

After a data set has been selected using one of the methods in section 9.5, the data is presented in chart format as shown on Figure 67. If multiple probes and / or instruments appear on the same view:

1. These may be shown or hidden by ticking / un-ticking the relevant check box from the region highlighted in red.
2. The chart legend region highlighted in green shows each the colour for each probe's hydrogen and temperature trace. These colours may be modified by selecting "Settings", "Chart line colours"

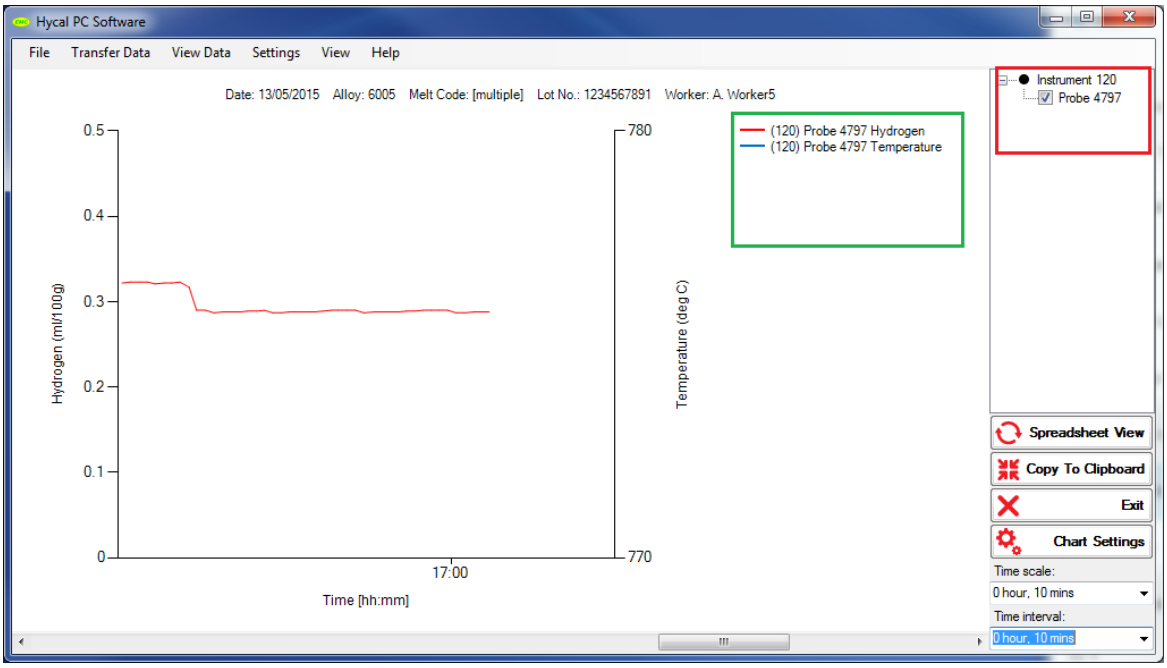


Figure 67: Chart view

The chart time base is adjusted using the time scale settings in the bottom right hand corner of the chart view screen. Use the horizontal scroll bar at the bottom of the chart to scroll to the previous / next data set.

9.6.1.1 Chart settings

Chart settings are shown on Figure 68. The user may change the hydrogen and temperature scale scales, marker and grid settings, temperature units, and control the information displayed on the chart title.

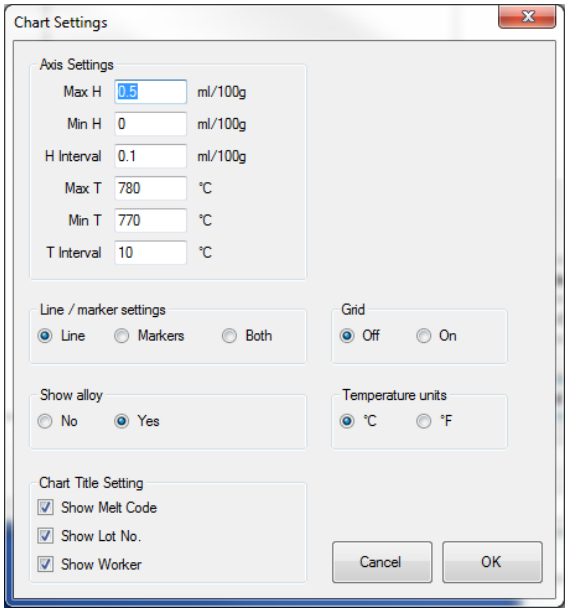


Figure 68: Chart settings

9.6.1.2 Printing a chart

A chart may be printed by selecting "File", "Print".

9.6.1.3 Saving a chart

A chart may be saved by selecting "File", "Save Chart" then selecting a file name and location to save the chart. This process creates a file with extension "daq" that contains all the raw data shown on the chart, i.e. the file is not dependent of the PC's database. This means that the file can, for example, be opened on a different computer, archived separately, or emailed to a third party provided they have the Hycal PC software installed on their machine.

9.6.1.4 Loading a saved chart

To load a saved chart, click "File", "Open Chart".

9.6.2 Spreadsheet view

Click the "Spreadsheet View" icon on the right-hand side of the chart view to view the raw data in numeric format as shown on Figure 69. The user may scroll through and examine the data or copy the data to the clipboard for pasting into an Excel spreadsheet or another program. Click "Chart View" to return to the chart view or "Exit" to return to the search page and select a different data set.

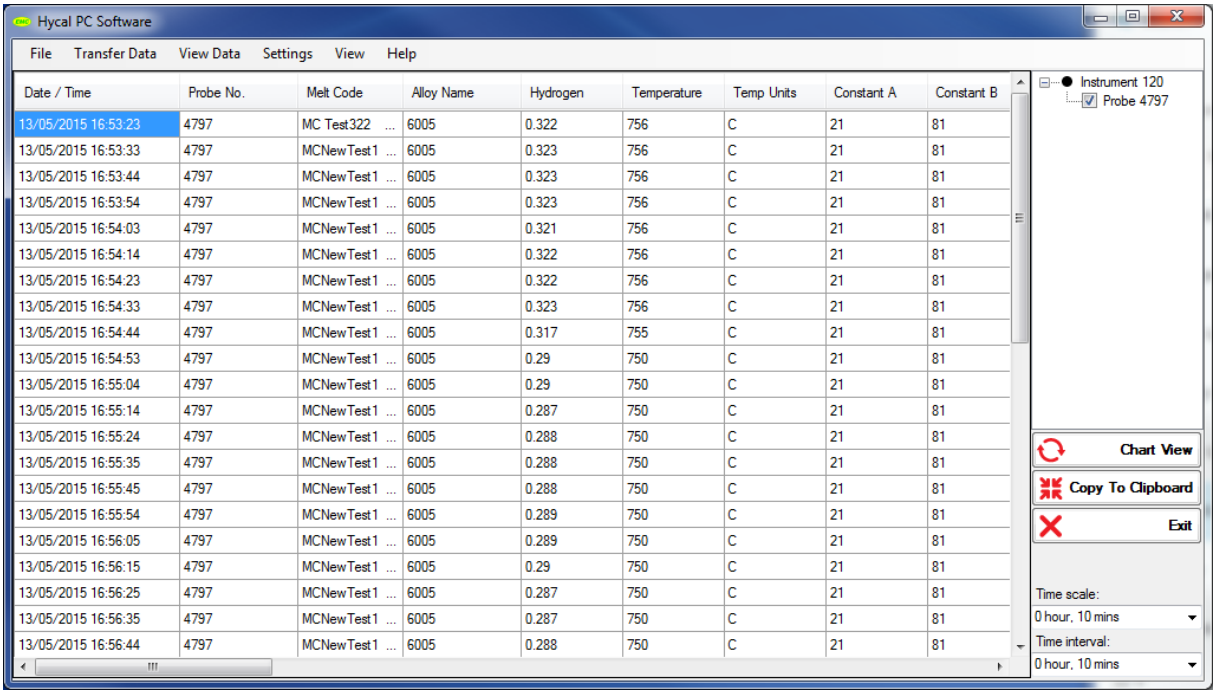


Figure 69: Spreadsheet view

9.7 Remote viewer

The remote viewer allows remote viewing and controlling of the Hycal analyser over Ethernet. To start the remote viewer, click the remote viewer icon on the Home screen (Figure 66), or click "View", "Remote Viewer". When prompted enter the Hycal's IP address and click "OK" to confirm the "Remote viewer starting message". The viewer will connect to the Hycal analyser and then prompt for the password. Enter the remote viewer password (**100**) then click OK. The Hycal screen will

appear on the PC and the Hycal analyser can be controlled in the same way as would be done locally. The remote viewer shows an exact copy of what is on the actual Hycal analyser display. Somebody local to the Hycal analyser can seen what is being done remotely and vice versa.

9.7.1 Connection options

By default the remote viewer connection options are optimised for appearance. If performance is slow (e.g. on a slow network), this may be improved by changing the connection options to 256 colours. Press "connection options", tick "256 colours (less traffic)" then OK. The connection will restart and should be significantly faster, at the expense of general appearance.

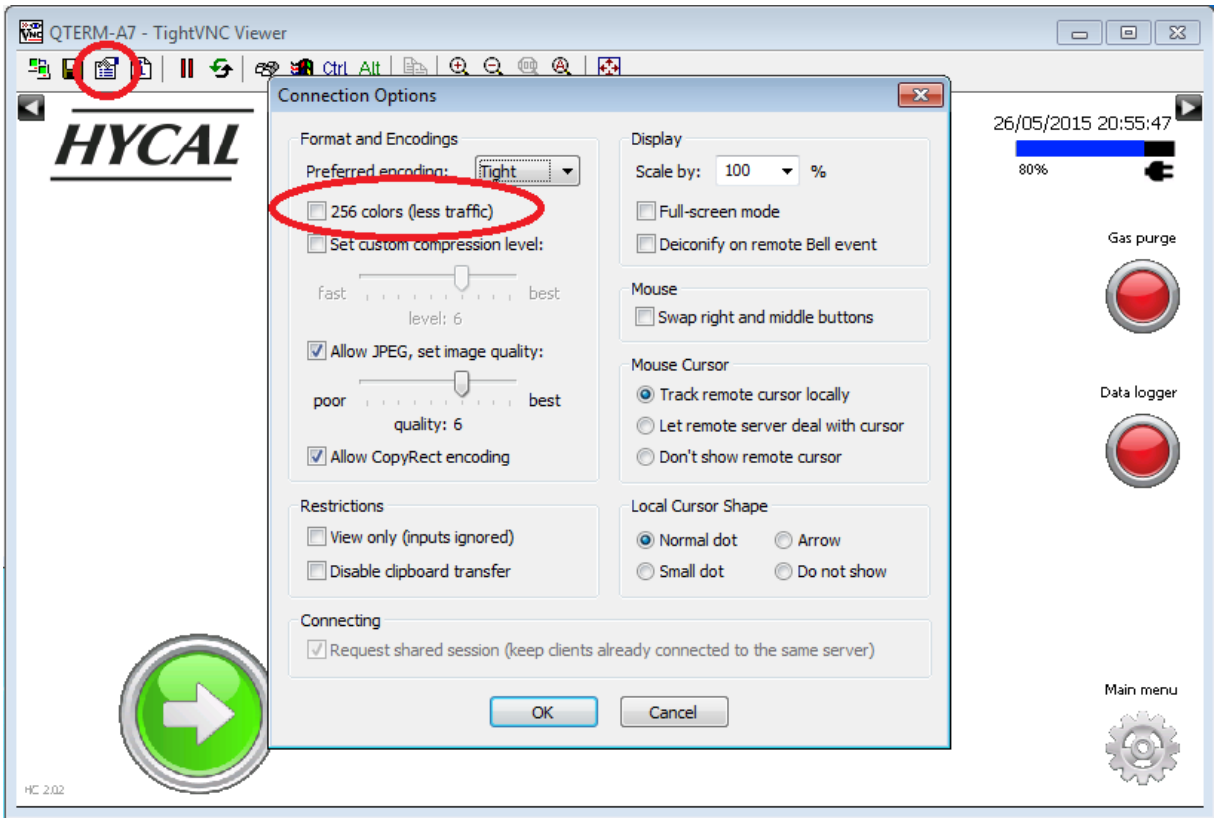


Figure 70: Remote viewer connection options

10 APPENDIX A – ALLOY CONSTANTS

Europe DIN EN 1676		UK	Germany DIN	France	USA	Japan		
Numeric	**Chemical**	**BS1490**	**1725/6**	**C.T.I.F**	**AA/ASTM**	**JIS**	**C**	**D**
	Pure Al						2692	1.726
	Al 99,5	LM 0		A 5	150.1		2692	1.700
21000	AlCu4MgTi		3.1372	A-5UGT	204.2		2692	1.600
21100	AlCu4Ti	LM 11	3.1842		224		2692	1.587
	AlCu10Si2Mg	LM 12		A-U10G	222		2692	1.391
41000	AlSi2MgTi						2692	1.702
42000	AlSi7Mg	LM 25		A-S7G	A356	AC4C	2692	1.622
42100	AlSi7Mg0,3		3.2335	A-S7G03	356.2	C4CV	2692	1.628
42200	AlSi7Mg0,6						2692	1.652
43000	AlSi10Mg(a)		3.2331	A-S9G	361.1	D3S	2692	1.592
43100	AlSi10Mg(b)	LM 9		A-S10G	A360	AC4A	2692	1.588
43200	AlSi10MG(Cu)		(233)	A-S9G	361.1	D3S	2692	1.572
43300	AlSi9Mg		3.2333	A-S10G	359.1	C4AV	2692	1.608
43400	AlSi10Mg(Fe)		3.2336		360.2		2692	1.577
44000	AlSi11		3.2212				2692	1.604
44100	AlSi12(b)	LM 6		A-S13	A413	AC3A	2692	1.549
44200	AlSi12(a)		3.2521				2692	1.553
44300	AlSi12(Fe)		(230)	A-S12	413.1	C3AS	2692	1.536
45000	AlSi6Cu4	LM 21	(225)	A-S5U2	308	AC2A	2692	1.478
45100	AlSi5Cu3Mg						2692	1.549
45200	AlSi5Cu3Mn	LM 4		A-S5U3	319	AC2A	2692	1.532
45300	AlSi5Cu1Mg	LM 16		A-S4UG	355	AC4D	2692	1.614
45400	AlSi5Cu3	LM 22		A-S5U3	319	AC2A	2692	1.531
46000	AlSi9Cu3(Fe)	LM 24	(226)	A-S9U3	380.1	ADC10	2692	1.469
46100	AlSi11Cu2(Fe)	LM 2		A-S9U3Y4	384	ADC12	2692	1.479
46200	AlSi8Cu3	LM 24	(226A)	A-S9U3Y	333.1	C4BS	2692	1.494
46300	AlSi7Cu3Mg						2692	1.505
46400	AlSi9Cu1Mg						2692	1.551
46500	AlSi9Cu3(Fe,Zn)	LM 24		A-S9U3A-Y4	A380	AC4B	2692	1.436
46600	AlSi7Cu2	LM 27				AC2B	2692	1.535
	AlSi9Cu3Mg	LM 26		A-S7U3G	332		2692	1.498
47000	AlSi12(Cu)	LM 20	3.2523	A-S12Y4	A413	C3AS	2692	1.527
47100	AlSi12Cu(Fe)	LM 2	231D	A-S12U	413.1		2692	1.517
48000	AlSi12CuNiMg	LM 13		A-S12UN	336	AC8A	2692	1.585

Europe DIN EN 1676		UK	Germany DIN	France	USA	Japan		
Numeric	**Chemical**	**BS1490**	**1725/6**	**C.T.I.F**	**AA/ASTM**	**JIS**	**C**	**D**
	AlSi17Cu4Mg	LM 30			390		2692	1.405
	AlSi191CuMgNi	LM 28		A-S18UNG	393.2		2692	1.544
	AlSi23CuMgNi	LM 29					2692	1.562
51000	AlMg3(b)						2692	1.900
51100	AlMg3(a)		3.3542	A-G3T	514.2		2692	1.904
51200	AlMg9		3.3293		518.2		2692	2.272
51300	AlMg5	LM 5	3.3562	A-G6	514	AC7A	2692	2.071
51400	AlMg5(Si)		3.3262	A-G6			2692	2.054
	AlMg10	LM 10			520.2	C7BV	2692	2.376
71000	AlZn5Mg	LM 31		A-Z5G	712		2692	1.632

11 APPENDIX B - COMMS SETTINGS

The Hycal can communicate with a SCADA system over Ethernet using the Modbus TCP protocol:

Hycal Modbus slave ID = 2

Addressing: 0 based[4]

Data format = Big Endian (Motorola)

Selected register numbers and data format are listed on Table 15. Other values are also available over Modbus which allow remote control of the Hycal by a 3rd party PLC (e.g. start purge, set alloy constants etc.), please contact EMC for more details.

Variable	Hycal Register(s)	Data type	Detail
Instrument number	40300	UINT16	0-9999
Data log export trigger	40301	UINT16	0-1
Data logger values	40302:40303	UINT32	Number of data entries
Hydrogen	40304:40305	Float	0.000-9.999
Temperature	40306:40307	Float	0-9999.9
Validated reading	40308	UINT16	0-1
Alloy	40309:40312	String	7 character alpha numeric
Melt code	40313:40317	String	10 character alpha numeric
Lot No.	40318:40322	String	10 character alpha numeric
Worker	40323:40327	String	10 character alpha numeric
Probe No.	40328:40330	UINT32	8 numeric characters
Melt code[5]	40331:40370	String	34 character alpha numeric

Table 15: MODBUS comms table

Note: Only register 40301 should be written to (triggers data log export).

[4] Example: Reading of register 40300 is achieved by reading the 301st holding register

[5] Time stamped

12 APPENDIX C – SPECIFICATIONS

Variant:	Hycal	Hycal 1000
Dimensions (excl. arm):	340 (W) x 266 (H) x 223 (D) mm	430 (W) x 400 (H) x 210 (D) mm
Weight:	8 kg	18 kg
Battery chemistry:	Li-ion	N/A
Battery life:	8 - 14 hours (brightness dependent)	N/A
Screen lighting:	LED	LED
Screen resolution:	800 x 480 WVGA, TFT colour LCD	800 x 480 WVGA, TFT colour LCD
Screen size:	7” (177 mm) diagonal	7” (177 mm) diagonal
Touch screen type:	Analogue-resistive with 4H hardness	Analogue-resistive with 4H hardness
Ethernet interface:	10/100Base-T, RJ45	10/100Base-T, RJ45
USB:	2.0 full-speed (Type A connector)	2.0 full-speed (Type A connector)
Max. power consumption:	210W (probe heater on, battery	210W (probe heater on, battery
Typical power consumption:	<10W (probe heater off, battery	<10W (probe heater off, battery
Power supply (external unit):	AC 85 - 265 V, 47 - 63 Hz	AC 85 - 265 V, 47 - 63 Hz
Operating temperature:	0 - 70°C	0 - 70°C
Humidity:	5 - 95% non-condensing	5 - 95% non-condensing

Table 16: Hycal specifications