HFR 400

Fast FID
Hydrocarbon Measurement System

Fault Diagnosis Manual

(Version 1.2)

Cambustion Ltd.

J6 The Paddocks

347 Cherry Hinton Road

Cambridge CB1 8DH

United Kingdom

Tel.: +44 1223 210250

Fax: +44 1223 210190

e-mail: support@cambustion.co.uk

URL: http://www.cambustion.co.uk

Introduction

This fault diagnosis manual is designed to assist users of modern HFR400 Fast FID systems. It applies to models built after May 1999, with the latest issue DCS system (DCS Serial Numbers 990191D and higher). Direct contact with Cambustion is always encouraged, but this manual contains much of the operating knowledge of Cambustion technicians who are also happy to discuss problems.

It is hoped that the illustrated text will assist in maintaining the equipment and will prevent unnecessary downtime. It is also hoped that this manual will enable users who were unable to attend the training talks and demonstrations given during the commissioning of the equipment to be trained to use and maintain the system.

How to use this fault diagnosis manual

The manual is split into two parts: The first half of the manual contains numbered Sections, each dealing with a different fault. The second half contains Appendices which relate to different parts of the system.

In each of the numbered sections, the user will find that the main heading is a description of a particular fault which may occur. Beneath that heading is a table which contains in its left column a list of questions. In the right column there is a reference relating to that question, telling the user which part of the Appendices to turn to for instructions on how to proceed.

Example:

Question	**Proceed to…**
Is the FID tube clean?	Yes – Next Question No – Appendix C.1

If the user is unsure of the answer to the question they should proceed by turning to the "No" part of the Appendix indicated where instructions on the tests are provided.

The user should work through the questions in order, as it is assumed that the previous questions have been answered "Yes".

Fuel Leaks

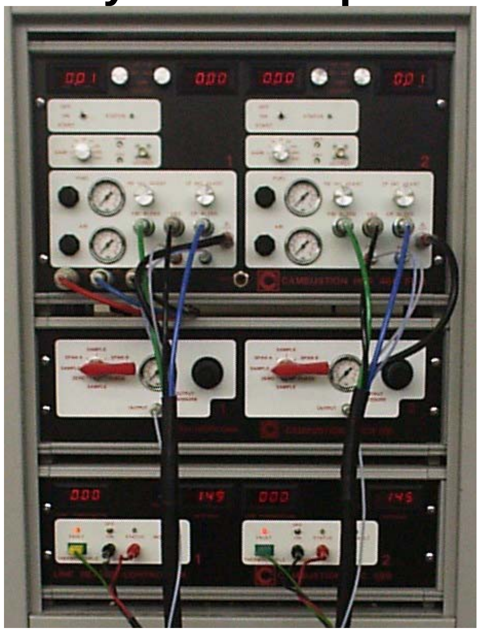
Ensure that there are no fuel leaks in the HFR400 system or the supply pipes to the system. The HFR400 Main Control Unit can be checked for fuel leaks by:

1. switching off the Fast FID electrical power supply
2. connecting the fuel supply pipe
3. pressurising the system to the 2 bar operating pressure
4. disconnecting the fuel supply pipe.

The fuel pressure gauge should remain at the operating pressure for at least 1 hour.

If the indicated pressure falls over this time, isolate the system from gas and electricity supplies and contact Cambustion for advice.

Names of system components

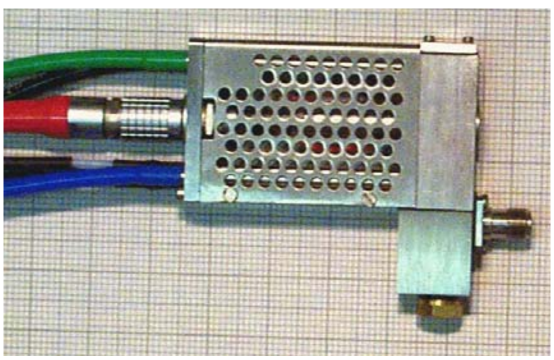


The control units of the system are shown left.

On the top is the MCU – Main Control Unit, which controls the services to the Fast FIDs, amplifies the signals from them and gives the analogue output from the system.

In the middle is the DCS – Dynamic Calibration System. This controls the gases used for calibrating the system.

On the bottom is the LHC – Line Heater Controller, which is used to maintain the temperature of the sample lines at the correct temperature.



This is the remote sample head – the HSM. It contains the Fast FID and the constant pressure sampling system to allow measurement of hydrocarbons in the exhaust of a running engine with ultra-fast response.

A typical system will have two HSMs which can be operated independently.

The TSL-H (and CAL-APT) is shown left. This sample line is connected to the HSM to enable sample to be taken from the sample point into the Fast FID.

The TSL-H has a narrow capillary along its centre, along which the sample is taken. This capillary is electrically heated by the LHC, to prevent condensation affecting the measurements taken with the Fast FID.

Common problems

FID does not light

Question	Proceed to...
Are you using the correct type of FID fuel?	Yes – Next question No – Appendix A.1
Is the fuel supply regulated at the bottle?	Yes – Next question No – Appendix A.2
Is the fuel gas flowing to the MCU?	Yes – Next question No – Appendix A.3
Is the fuel supply line correctly connected to the front of the MCU?	Yes – Next question No – Appendix B.1
MCU fuel gauge indicates pressure of at least 2 bar?	Yes – Next question No – Appendix B.4
Fuel pipe to HSM correctly connected to MCU?	Yes – Next question No – Appendix B.6
Sufficient flow along fuel line to HSM?	Yes – Next question No – Appendix B.9
Correct zero air type?	Yes – Next question No – Appendix A.4
Sufficient air pressure at supply?	Yes – Next question No – Appendix A.5
Is air flowing from the supply to the MCU?	Yes – Next question No – Appendix A.6
Air supply line connected to front of MCU (via DCS)?	Yes – Next question No – Appendix B.2
Sufficient air pressure at MCU?	Yes – Next question No – Appendix B.5
Air line to HSM correctly connected to MCU?	Yes – Next question No – Appendix B.7
Sufficient flow along air line to HSM?	Yes – Next question No – Appendix B.10
Vacuum pump functioning correctly?	Yes – Next question No – Appendix A.7
Vacuum line connected to MCU?	Yes – Next question No – Appendix B.3

FID Bleed / VAC / CP Bleed correctly connected?	Yes – Next question No – Appendix B.8
Correct CP VAC and FID ΔP achievable?	Yes – Next question No – Appendix B.11
LEMO connections correct?	Yes – Next question No – Appendix B.12
TSL-H correctly connected?	Yes – Next question No – Appendices C.2.2 and F.6
LHC switched on and heating TSL-H to set point temperature?	Yes – Next question No – Appendix E.1 to E.5
FID temperature reads approximately ambient?	Yes – Next question No – Appendix C.5
Status LED glows red when START switch depressed?	Yes – Next question No – Appendix B.13
Is HSM operating in a room at temperature higher than 0^oC?	Yes – Next question No – Appendix C.6
Has tee-piece been cleaned recently?	Yes – Next question No – Appendix C.1
Solenoid valves in MCU open correctly?	Yes – Next question No – Appendix B.14
Temperature rises when START switch held down?	Yes – Next question No – Appendix C.7
Several lighting attempts made?	Yes – Next question No – Appendix C.8
Are CP and FID chambers clean of oil and water?	Yes – Next question No – Appendix C.9 and C.16
Tee-piece seal is correctly fitted and undamaged?	Yes – Next question No – Appendix C.10
O-rings on burner correctly fitted and undamaged?	Yes – Next question No – Appendix C.11
Glow plug filament protruding into FID chamber by 3mm?	Yes – Next question No – Appendix C.12
HSM fuel and air restrictors clean?	Yes – CONTACT CAMBUSTION No – Appendix C.13

Flame keeps extinguishing

Question	Proceed to…
Fuel type correct?	Yes – Next question No – Appendix A.1
Zero air type correct?	Yes – Next question No – Appendix A.4
Fuel supply pressure at least 3 bar?	Yes – Next question No – Appendix A.2
Air supply pressure at least 5 bar?	Yes – Next question No – Appendix A.5
Fuel supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.1
Air supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.2
Fuel pressure, measured on MCU front panel, approximately 2 bar?	Yes – Next question No – Appendix B.4
Air pressure, measured on MCU front panel, approximately 4 bar?	Yes – Next question No – Appendix B.5
HSM fuel line correctly connected to MCU?	Yes – Next question No – Appendix B.6
HSM air line correctly connected to MCU?	Yes – Next question No – Appendix B.7
FID Bleed / VAC / CP Bleed connections correct?	Yes – Next question No – Appendix B.8
FID ΔP and CP VAC correct?	Yes – Next question No – Appendix B.11
TSL-H correctly connected?	Yes – Next question No – Appendices C.2.2 and F.6
TSL-H at operating temperature?	Yes – Next question No – Appendix E.1 to E.5
Are CP and FID chambers clean of oil and water?	Yes – Next question No – Appendix C.9 and C.16
Tee-piece seal is correctly fitted and undamaged?	Yes – Next question No – Appendix C.10
O-rings on burner correctly fitted and undamaged?	Yes – Next question

	No – Appendix C.11
HSM fuel and air restrictors clean?	Yes – Next question No – Appendix C.13
HSM checked for leaks (if possible when lit)?	Yes – Next question No – Appendix C.2
Is HSM operating in a room at temperature > 0^oC?	Yes – Next question No – Appendix C.6
FID tube cleaned?	Yes – CONTACT CAMBUSTION No – Appendix C.1

Large zero offset

Question	Proceed to...
Certain that the sample head has not been consuming sample from engine whilst FID flame not lit?	Yes – Next question No – Appendix F.8
Has the head warmed up?	Yes – Next question No – Appendix C.15
Is HSM operating in a room at temperature > 0^oC?	Yes – Next question No – Appendix C.6
Is the DCS set to zero?	Yes – Next question No – Appendix D.3
Is the DCS being supplied with HC free zero gas?	Yes – Next question No – Appendices A.4 and B.2.1.
Does the offset remain when the BNC signal cable at the MCU is disconnected?	Yes – Next question No – Appendix B.19
Is the ZERO screw set correctly?	Yes – Next question No – Appendix B.15
Are CP and FID chambers clean of oil and water?	Yes – Next question No – Appendix C.9 and C.16
Is the collector clean?	Yes – Next question No – Appendix C.16
Has TSL-H been cleaned recently?	Yes – Next question No – Appendix F.2
Has tee-piece been cleaned recently?	Yes – Next question No – Appendix C.1
Collector overheating?	Yes – CONTACT CAMBUSTION No – Appendix C.17

Excessive SPAN drift

Question	Proceed to...
Fuel pressure, measured on MCU front panel, approximately 2bar?	Yes – Next question No – Appendix B.4
Air pressure, measured on MCU front panel, approximately 4bar?	Yes – Next question No – Appendix B.5
HSM clear of any air stream from cooling fan in test-cell?	Yes – Next question No – Appendix C.19
Tee-piece clean?	Yes – Next question No – Appendix C.1
Capillary in TSL-H probe clean?	Yes – Next question No – Appendix F.2
Is TSL-H switched on?	Yes – Next question No – Appendix E.1
Is HSM operating in a room at temperature > $0^{o}C$?	Yes – Next question No – Appendix C.6
Is the air supply pressure stable (not intermittent air compressor operation)?	Yes – CONTACT CAMBUSTION No – Appendix A.5

Noisy signal

Question	Proceed to...
Fuel pressure measured on MCU front panel, approximately 2 bar?	Yes – Next question No – Appendix B.4
Air pressure measured on MCU front panel, approximately 4 bar?	Yes – Next question No – Appendix B.5
FID ΔP and CP VAC correct?	Yes – Next question No – Appendix B.11
Sample head checked for leaks?	Yes – Next question No – Appendix C.2
Noise remains when heated line switched off?	Yes – Next question No – Appendix F.7
Sufficient calibration gas pressure on DCS?	Yes – Next question No – Appendix D.2 and D.4
Tee-piece clean?	Yes – Next question No – Appendix C.1
Poor earth connection at MCU/on engine/in HSM?	Yes – Next question No – Appendix G.1
TSL-H sample probe clean?	Yes – Next question No – Appendix F.1
Is capillary undamaged (check using section F.4)?	Yes – Next question No – Appendix F.4
Is HSM operating in a room at temperature > 0^{o}C?	Yes – Next question No – Appendix C.6
Is the HSM mounted in a location free from vibration?	Yes – Next question No – Appendix C.18
Is the vacuum supply from a Cambustion supplied rotary vacuum pump?	Yes – Next question No – Appendix A.7
TSL-H correctly fitted?	Yes – CONTACT CAMBUSTION No – Appendix F.6

Cannot set required vacuums

Question	Proceed to...
Vacuum pump on and pipe free from blockages?	Yes – Next question No – Appendix A.7
Vacuum pump black 6mm supply pipe shorter than 3m?	Yes – Next question No – Appendix A.7, B.3
FID Bleed, VAC and CP Bleed connections made correctly?	Yes – Next question No – Appendix B.8
Is the brass plug in the base of the CP chamber fitted correctly?	Yes – Next question No – Appendix H.1 and C.1
Are the CP, TNC, FID lid gaskets and inspection hatch and o-ring all fitted correctly?	Yes – Next question No – Appendix H.1
TSL-H screwed on finger tight?	Yes – Next question No – Appendix F.6
TSL-H capillary undamaged?	Yes – Next question No – Appendix F.4
Sample head checked for leaks?	Yes – Next question No – Appendix C.2
Restrictor in CP vacuum line on rear of HSM clean?	Yes – Next question No – Appendix C.14
Is HSM operating in a room at temperature > 0^{o}C?	Yes – CONTACT CAMBUSTION No – Appendix C.6

Low flame temperature (i.e. <150°C)

Question	Proceed to...
Fuel pressure, measured on MCU front panel, approximately 2 bar?	Yes – Next question No – Appendix B.4
Air pressure, measured on MCU front panel, approximately 4 bar?	Yes – Next question No – Appendix B.5
Tee-piece clean?	Yes – Next question No – Appendix C.1
Tee-piece seal in good condition?	Yes – Next question No – Appendix C.10
O-rings on burner in good condition?	Yes – Next question No – Appendix C.11
HSM fuel line correctly connected to MCU?	Yes – Next question No – Appendix B.6
HSM air line correctly connected to MCU?	Yes – Next question No – Appendix B.7
FID ΔP correctly set?	Yes – Next question No – Appendix B.11
Is HSM operating in a room at temperature > 0^oC?	Yes – Next question No – Appendix C.6
Thermocouple correctly connected?	Yes – Next question No – Appendix C.20
Thermocouple correctly positioned?	Yes – CONTACT CAMBUSTION No – Appendix C.21

Signal optimises at non-standard fuel and air pressures

Question	Proceed to...
Fuel type correct?	Yes – Next question No – Appendix A.1
Fuel pressure, measured on MCU front panel, approximately 2 bar?	Yes – Next question No – Appendix B.4
Air pressure, measured on MCU front panel, approximately 4 bar?	Yes – Next question No – Appendix B.5
Fuel supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.1
Air supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.2
Sufficient flow along fuel line to HSM?	Yes – Next question No – Appendix B.9
Sufficient flow along air line to HSM?	Yes – Next question No – Appendix B.10
Are you using a standard (less than 3,000ppm C_3 balance N_2) calibration span gas?	Yes – CONTACT CAMBUSTION No – Appendix A.8

No (or low) signal levels

Question	Proceed to...
Is flame lit (temperature still above 110^{o}C)?	Yes – Next question No – Appendix C.2
DCS set to SAMPLE / SPAN A / SPAN B?	Yes – Next question No – Appendix D.3
Fuel supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.1
Air supply correctly connected to front panel of MCU?	Yes – Next question No – Appendix B.2
Fuel pressure, measured on MCU front panel, approximately 2bar?	Yes – Next question No – Appendix B.4
Air pressure, measured on MCU front panel, approximately 4bar?	Yes – Next question No – Appendix B.5
FID ΔP and CP VAC correct?	Yes – Next question No – Appendix B.11
Tee-piece clean?	Yes – Next question No – Appendix C.1
Sample line clean?	Yes – Next question No – Appendix F.2
GAIN set correctly?	Yes – Next question No – Appendix B.16
SPAN screw set correctly?	Yes – Next question No – Appendix B.17
Is high voltage collector operating at high voltage?	Yes – Next question No – Appendix B.20
Flame stabilised on the glow-plug	Yes – CONTACT CAMBUSTION No – Appendix C.22

Dynamic calibration signal not flat

Question	Proceed to...
Check ΔP stable	Yes – Next question No – Appendix C.3
Check CP stable	Yes – Next question No – Appendix C.4
HSM free from internal and external leaks?	Yes – Next question No – Appendix C.2
HSM free from vibration?	Yes – Next question No – Appendix C.18
Does pressure gauge rise when calibration gas selected?	Yes – Next question No – Appendix D.3
Check span pressure sufficient for engine condition	Yes – Next question No – Appendix D.2
When engine stopped, does non-flat signal persist?	Yes – Next question No – Appendix D.4.2
When sampling outside engine, does non-flat signal persist?	Yes – Next question No – Appendix D.4.3
Check panel meter and scope agree	Yes – Next question No – Appendix B.18
Does non-stable signal as displayed on the panel meter output still appear when signal BNC is disconnected from MCU front panel?	Yes – CONTACT CAMBUSTION No – Appendix B.19

LHC/TSL-H not working properly

Question	Proceed to...
MCB fault light unlit?	Yes – Next question No – Appendix E.2
Status light illuminates green?	Yes – Next question No – Appendix E.3
Thermocouple fault light unlit?	Yes – Next question No – Appendix E.4
Is the LEMO correctly connected?	Yes – Next question No – Appendix F.5
LHC Power leads connected to front panel correctly?	Yes – Next question No – Appendix E.5
Line temperature rises when line switched on?	Yes – Next question No – Appendix F.3.1
Line temperature stable at setpoint?	Yes – CONTACT CAMBUSTION No – Appendix F.3.2

APPENDICES

Appendix A Services check procedures

A.1 Fuel supply overview

Make sure that the fuel gas being used is the correct type. The HFR400 system is designed to operate on pure H_2. However, in certain circumstances, the system may have been modified to operate on H_2/He mix. Specifications for the fuel gas can be found in the Appendices of the HFR400 User Guide.

A.2 Fuel supply pressure

The fuel supply pressure to the HFR400 should be 3bar. If the regulator attached to the supply cannot give a pressure of at least 3bar, it should be changed.

A.3 Checking for blockages in fuel supply line

Check that the fuel gas is able to flow to the MCU from the supply. If there are shut-off valves in the supply line these should be opened – if the pipe has been crushed or is blocked in some other way it should be replaced.

A.4 Zero air supply overview

Make sure that the gas being used as zero air is the correct type. The HFR400 uses (when equipped with a DCS400 Calibration system) the same gas for both the calibration zero air and the FID flame air. For this reason, the zero air used *must* be HC-free air, and not N_2 (or some other inert gas). Specifications for the zero air can be found in the Appendices of the HFR400 User Guide.

A.5 Air supply pressure

The air supply pressure to the HFR400 should be at least 5bar. If the regulator attached to the supply cannot give a pressure of at least 5bar, it should be changed. Ideally, the air supply should be from a bottle, as a poorly regulated supply from a compressor can lead to signal drift.

A.6 Checking for blockages in air supply line

Check that the zero air is able to flow to the MCU from the supply. If there are shut-off valves in the supply line these should be opened – if the pipe has been crushed or is blocked in some other way it should be replaced.

A.7 Vacuum pump overview

The vacuum pump should be filled to the correct fill level with suitable oil, and only operated on a flat surface at least 0.6m (2 feet) below the MCU to which it is connected. The black 6/4 plastic pipe connecting the pump to the system must not be more then 3m in length.

The vacuum pump must be switched on. The pump should generate a vacuum of at least 500mmHg (gauge) with a flow of at least 2 litres/min STP per channel in use. Oscillating diaphragm vacuum pumps should not be used as they will not produce a steady vacuum, resulting in increased noise.

A.8 Calibration (SPAN) gas specification

Try to use a calibration span gas which closely resembles the HC concentration you expect to measure (e.g. for exhaust measurements, a calibration gas between 1,000ppm C_3 and 2,000ppm C_3 balance N_2 would be suitable).

If very high [HC] span gas is used, accurate optimising of the FID fuel pressure is difficult.

It is difficult to record accurate results when calibrating with an unsuitable gas.

Appendix B MCU check procedures

B.1 Fuel supply connection to MCU

The Swagelok fitting on the end of the fuel supply line must be pushed into the fitting on the front panel of the MCU (marked **FUEL** in Figure 1) until a click is heard. Otherwise the connection has not been made, and no fuel can flow.

Figure 1

B.2 Air supply connection to MCU

B.2.1 With DCS

The Swagelok fitting on the end of the zero air supply line must be pushed into the fitting on the front panel of the MCU (marked **AIR** in Figure 1) until a click is heard. Otherwise the connection has not been made, and no air can flow.

If a DCS400 Calibration unit is being used, the zero air supply will be connected to the rear panel of the DCS (to the **ZERO IN** connection). The blue connecting pipe should be used to take zero air to the MCU from the fitting marked **ZERO OUT** on the rear of the DCS (see Figure 2). All of the Swagelok connections should be connected with a firm push.

B.2.2 Without DCS

The zero air pipes should be connected directly into the front panel of the MCU as shown in Figure 1.

Figure 2

B.3 Vacuum supply connection to MCU

The vacuum should be connected to the **VAC** connection on the front panel of the MCU, as shown in Figure 1. The Swagelok quick connections should be made correctly as described above. The pipe should *not* be fitted with shut-off fittings, as these tend to become blocked with particulates over time.

B.4 Fuel pressure at MCU

The fuel pressure available from the MCU is adjustable independently for each channel. If this pressure cannot be adjusted to a value of at least 2 bar (the regulator and gauge are marked **FUEL**), then there is a leak or blockage inside the MCU.

ISOLATE THE EQUIPMENT AND CONTACT CAMBUSTION IMMEDIATELY.

B.5 Air pressure at MCU

The air pressure available from the MCU is adjustable independently for each channel. If this pressure cannot be adjusted to a value of at least 4bar (the regulator and gauge are marked **AIR** as shown in Figure 1), then there is a leak or blockage inside the MCU.

CONTACT CAMBUSTION

B.6 HSM fuel line connection

The fuel line to the HSM is made from 1/8" PTFE pipe, and is marked with a red line. This line should be connected to the outlet marked **FUEL** as shown in Figure 3. Care should be taken that the fuel and air lines are correctly connected to the appropriate outlet. Also check the connections to the extension cables (if fitted).

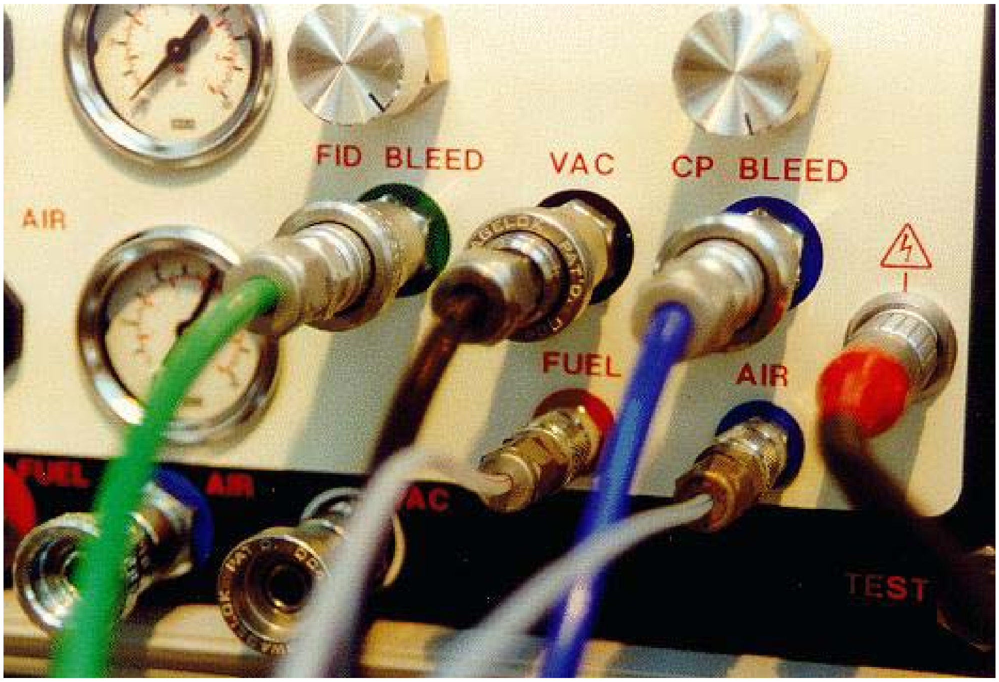


Figure 3

B.7 HSM air line connection

The air line to the HSM is made from 1/8" PTFE pipe, and is marked with a blue tracer. This line should be connected to the outlet marked **AIR** as shown in Figure 3. Care should be taken that the air and fuel lines are correctly connected to the appropriate outlet. If extension cables are fitted, ensure that these pipes are correctly connected as it is possible to connect the air to the fuel outlet (and vice versa) by mistake.

B.8 FID Bleed / VAC / CP Bleed connections

The FID Bleed, VAC and CP Bleed lines to the MCU from the HSM should be correctly connected. Ensure that the Swagelok fittings on the end of these lines are pushed into the correct fittings on the front panel of the MCU (marked **FID BLEED**, **VAC** and **CP BLEED** in Figure 3) until a click is heard. The FID Bleed, VAC and CP Bleed pipes are coloured Green, Black and Blue respectively, as are the fittings on the front panel of the MCU. If EXT or EXT-Q extension cables are being used, the connections should be checked at the end of the extension as well as the front of the MCU.

B.9 Fuel flow to HSM

Connect a rotameter into the **FUEL** outlet on the front of the MCU (as shown in Figure 4). Ensure the LEMO is correctly connected (see Section 29), depress the OFF/ON/START switch to START, and observe the flow of fuel through the rotameter. This flow should be approximately 12cc/min (±5cc/min). If this is not the case, adjust the fuel pressure using the regulator on the front of the MCU until the flow meets this criterion (a pressure of approximately 2 bar should be sufficient for modern units). If this flow cannot be achieved, there is a problem within the MCU. Check the solenoid valves in the MCU are opening correctly (Section B.14), and that the Status LED is changing colour when the unit is switched to START (Section B.13). If these are working correctly, then the fuel restrictor for this channel is blocked or broken.

ISOLATE THE EQUIPMENT AND CONTACT CAMBUSTION IMMEDIATELY.

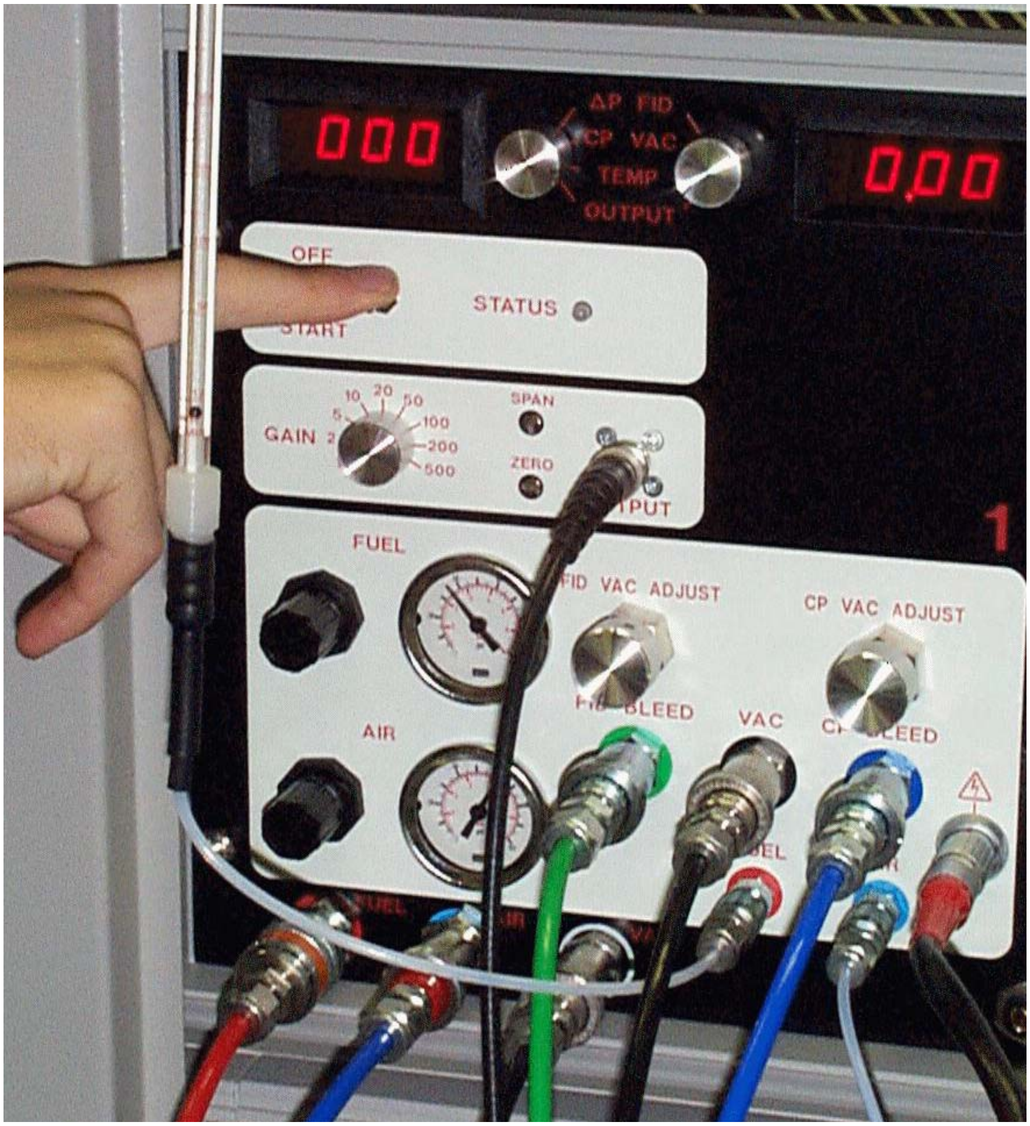


Figure 4

B.10 Air flow to HSM

Connect a rotameter into the **AIR** outlet on the front of the MCU (as shown in Figure 5). Ensure the LEMO is connected, then depress the OFF/ON/START switch to START, and observe the flow of fuel through the rotameter. This flow should be approximately 250cc/min (±50cc/min).

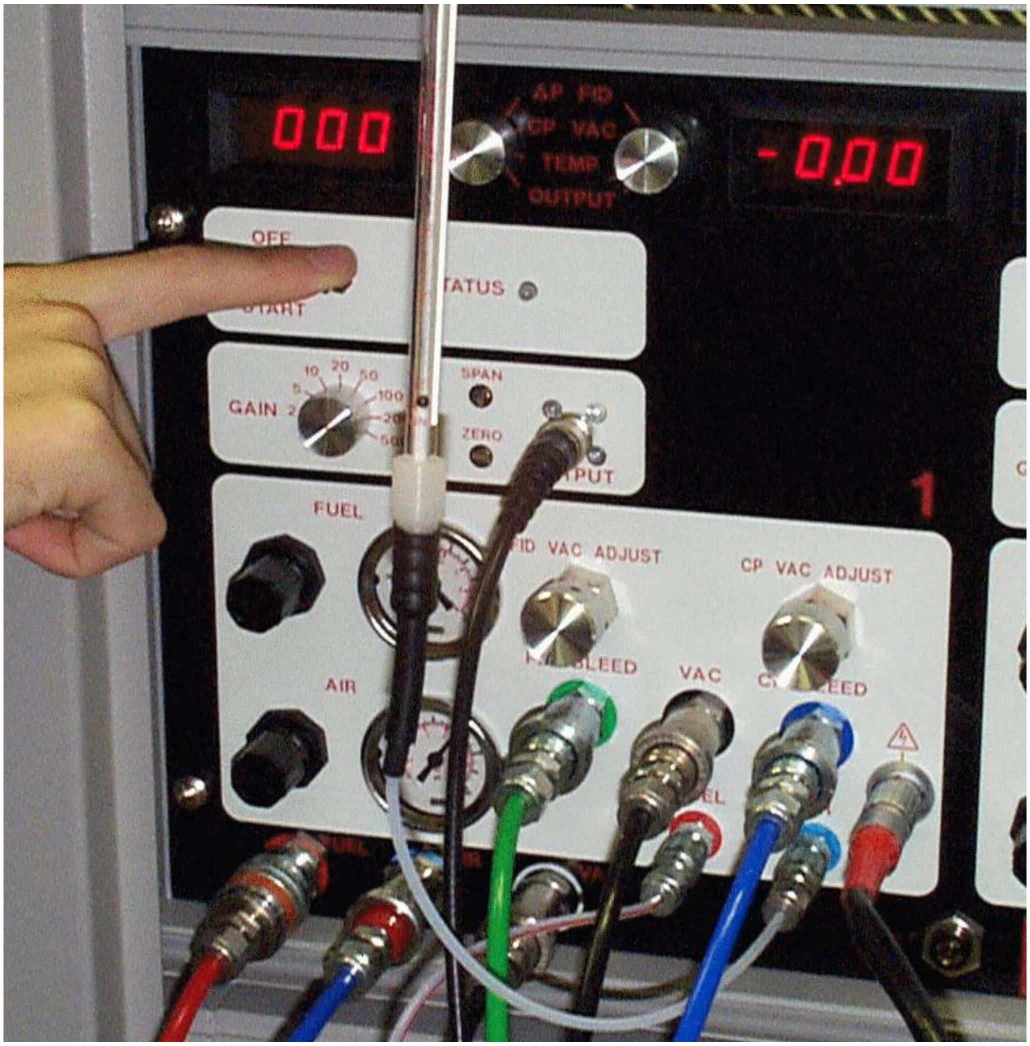


Figure 5

If this is not the case, adjust the air pressure using the regulator on the front of the MCU until the flow meets this criterion (a pressure of approximately 4bar should be sufficient for modern units). If this flow cannot be achieved, there is a problem with the MCU. Check the solenoid valves in the MCU are opening correctly (Section B.14), and that the Status LED is changing colour when the unit is switched to START (Section B.13). If these are working correctly, then the air restrictor for this channel is blocked or broken.

CONTACT CAMBUSTION FOR REPAIR ADVICE.

B.11 Checking correct ΔP and CP can be achieved

For normal exhaust sampling applications, set CP = 300mmHg and ΔP = 100mmHg (H_2 fuel and 0.008″ {yellow} tee-piece. Use CP=300 and ΔP = 50mmHg for H_2/He fuel and 0.010 {blue} tee-piece). If you cannot achieve these vacuums, see Common problems section – cannot achieve required vacuum.

B.12 LEMO connections

B.12.1 At MCU

The LEMO electrical connector should be pushed fully into the connector on the front of the MCU, otherwise the interlock circuitry of the MCU will not open the fuel and air solenoids to supply the FID flame in the HSM. If EXT or EXT-Q extension cables are being used the line LEMO connection at the end of the extension should also be checked, as well as the connection to the front of the MCU.

B.12.2 At HSM

There is a LEMO connection on the rear bulkhead of the HSM. The connector should be pushed fully into the connector on the bulkhead, otherwise the interlock circuitry of the MCU will not open the fuel and air solenoids to supply the FID flame in the HSM.

B.12.3 With EXT-Qs

Check that the LEMO connections in the extension cables are connected properly.

B.13 Status LED on MCU

With the HSM connected correctly to the MCU, depress the START switch. The LED labelled **STATUS** should glow red as the switch is first depressed. If this is not the case (and the thermocouple / thermocouple circuit has not failed – see Section C.20) there is a fault in the glow plug circuit. Swap the HSM to the other channel. If the fault moves with the HSM (and appears on the other channel) then the glow plug (or the wiring to it in the HSM or service cable) has failed and will need replacing. Otherwise there is a fault on the circuit board of the MCU.

B.14 Solenoid valves in MCU

With the HSM connected correctly to the MCU, depress the START switch. There should be a hissing sound for a few seconds, as the vacuum release solenoid opens. There should also be a faint click heard as the switch is released, due to the fuel and air solenoids shutting.

If possible, remove the lid of the MCU and observe the lights on the top of each of the solenoids. Be careful to avoid touching the internal components in case of electric shock. The fuel and air solenoids are mounted below the vacuum regulators on the back of the front panel, and the vacuum release solenoid is mounted on a stub of pipe just below the FID Bleed regulator, as shown in Figure 6. If these lights do not glow when the START switch is depressed, there is a fault either with the solenoid or its drive circuit. (Note the vacuum release solenoid will only operate for a few seconds immediately after the START switch is depressed.)

Swap the HSM to the other channel of the and check if the problem remains with the HSM or with the MCU channel.

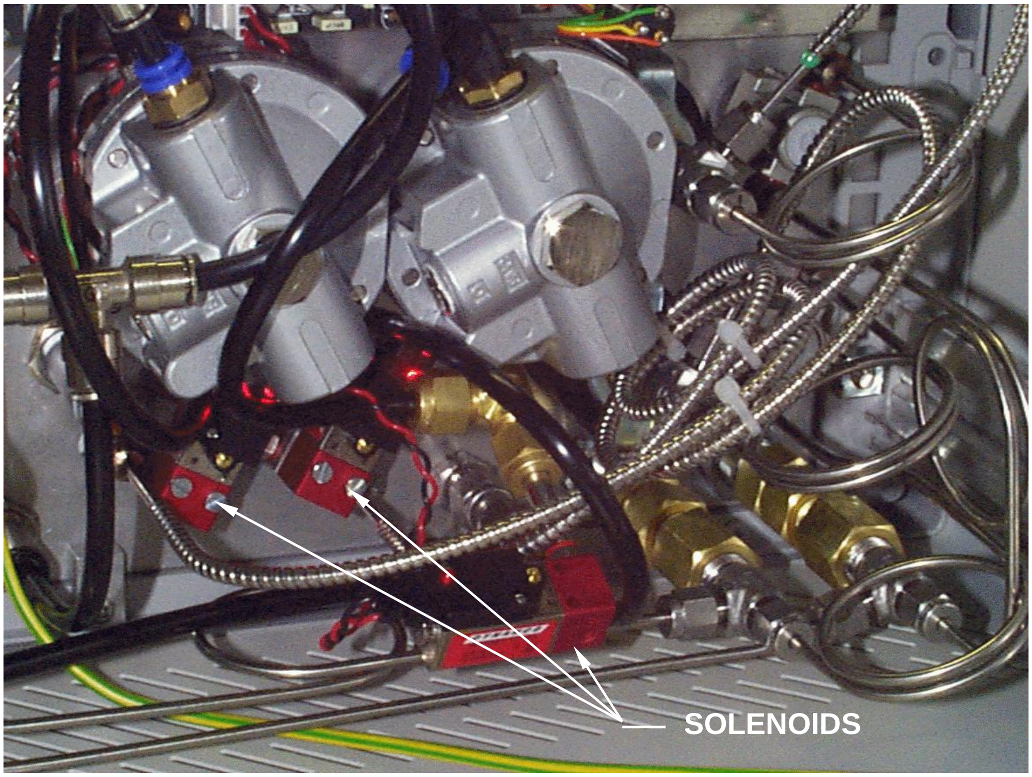


Figure 6

B.15 ZERO screw setting

The normal position of the ZERO screw is 5 full (360 degree) turns from either end stop. At this point, the HFR400 panel meter should be showing an offset of < 0.5V, if no other offset problem exists.

B.16 GAIN switch settings

For normal exhaust sampling, a GAIN setting of 100, 200 or 500 is normal. If the GAIN is set to 10 or less, very little signal will be displayed. A typical HSM should give an output of 2-3V when supplied with SPAN gas of 1800ppmC_3, the FID fuel set to 2bar, FID air set to 4bar, GAIN set to 100 and the SPAN screw turned fully clockwise.

B.17 SPAN screw setting

Turn the span screw fully clockwise to maximise the output on the selected coarse GAIN range. The SPAN screw can then be turned to give the correct calibrated output when the calibration gas is applied.

B.18 Checking panel meter with oscilloscope

The panel meters have been calibrated before dispatch from Cambustion. Check that they are still displaying the correct voltages by comparing both meters on each channel with an oscilloscope or voltmeter connected to the output BNC connector. You can simulate a signal by applying an offset using the ZERO screw.

B.19 BNC output connection

Remove the BNC cable from the front of the MCU. If the drift, offset or noise problem is solved by the removal of this BNC connection, a ground-loop problem exists. Ensure that the analyser, the sample head (and therefore the engine) and the oscilloscope are all correctly grounded.

B.20 Failure of the high voltage collector power supply

When the analyzer is lit and calibration gas is applied, turn the span screw fully clockwise and the GAIN set to 500. If you see a very low output (approximately 1% of the expected output), it is likely that the H-T power supply to the collector has failed.

CONTACT CAMBUSTION FOR ADVICE.

Appendix C HSM check procedures

C.1 Cleaning the FID tube

If the tee-piece has become blocked the flame may be difficult to light.
To clean the tee-piece:

1. Remove the electrical LEMO connection of the HSM from the MCU and swivel the HSM over on to its side on the ball joint of the tripod (Figure 7).

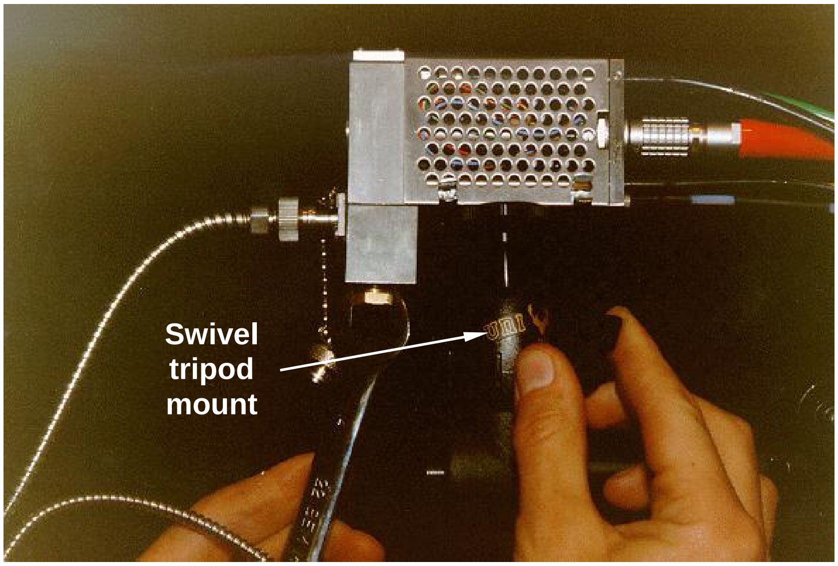


Figure 7

2. Remove the brass plug from the base of the sample head CP chamber. Inside is a tube with a coloured spot: yellow for a 0.008″ i/d tee-piece, blue for a 0.010″ i/d tee-piece (Figure 8).

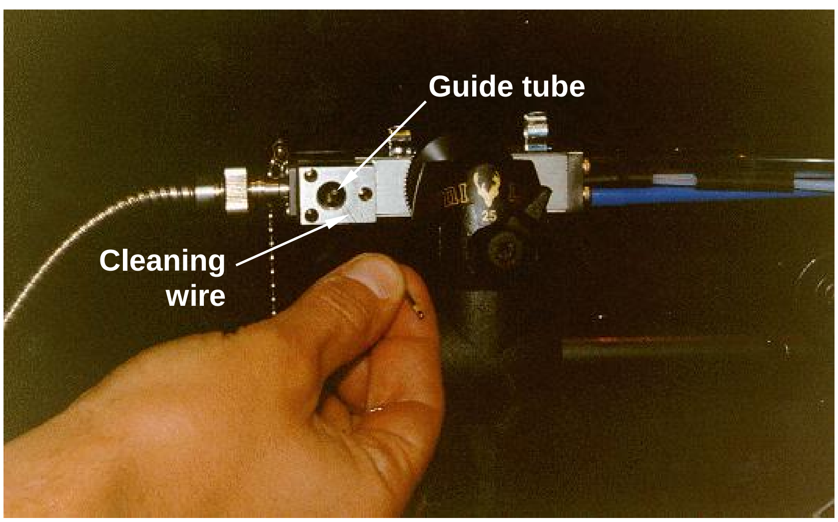


Figure 8

3. Use the cleaning wire with the same colour coding from the tool kit.
4. Insert the wire into the guide tube and rotate while pushing it up to the shoulder.
5. Remove the wire and re-fit the brass plug.

C.2 Leak checking the HSM

C.2.1 Checking the HSM for internal leaks

When the FID is lit and sampling zero gas, hold an unlit butane gas lighter up to the "TEST" port on the front panel of the MCU. The output on the panel meter should remain at 0.00V. If this level rises, check the items shown in sections F.2 and C.11.

C.2.2 Checking the HSM for external leaks

When the FID is lit and sampling zero gas, hold an unlit butane gas lighter at the following locations to check for leaks into the chamber:

- CP Gasket
- TNC Gasket
- TSL-H seal
- Flexible part of TSL-H
- Rear of the sample head (though mesh noise shield)

The output on the panel meter should remain at 0.00V. If this level rises, refer to the main user manual and video supplement for leak repairs.

C.3 Checking for stable FID ΔP

Stable signals require the ΔP to be constant. Select **ΔP FID** on the panel meter when sampling in the running engine and check that the value remains stable (+/- 1 mmHg). If it is unstable, read section C.4.

C.4 Checking for stable CP vacuum

Select **CP VAC** on the panel meter with the engine running and check the **CP VAC** value for stability (+/- 3mmHg).

If the **CP VAC** value is unstable, the CP chamber must be extended to accommodate the unusually high flows which are being admitted to the chamber.

Also, a capillary insert may be fitted to the TSL-H sample probe which will reduce the flow rate of gas into the chamber and prevent large pressure variations.

CONTACT CAMBUSTION FOR MORE ADVICE

C.5 Checking HSM temperature

With the HSM connected correctly to the MCU, select **TEMP** on one of the panel meters on the front panel of the MCU, as shown in Figure 9.

Figure 9

If the panel meter gives a reading of 000, rather than approximately the ambient temperature of the room the HSM is in, then there is a fault in the thermocouple circuit. Swap the HSM to the other channel. If the fault moves with the HSM (and appears on the other channel) then the thermocouple (or the wiring to it in the HSM or service cable) has failed and will need replacing. Otherwise there is a fault on the circuit board of the MCU.

CONTACT CAMBUSTION FOR REPAIR ADVICE.

C.6 Cold cell operation of HSM

If the HSM is currently in a cold-room then the flame will not light due to excessive quenching at low temperatures and possibly freezing of the vacuum restrictors causing loss of vacuum. Operation at temperatures lower than 0°C requires trace heating of the HSM service pipes and insulation of the HSM sample head.

Remove the HSM from the cold-room, and attempt to re-light the flame at ambient conditions. Once the flame is re-lit, the HSM can be put back into the cold-room with appropriate trace heating and insulation.

CONTACT CAMBUSTION FOR MORE ADVICE.

C.7 FID temperature during lighting

With the HSM correctly connected, depress the START switch. If the temperature displayed on the panel meter at the top of the front panel of the MCU (see Figure 9) rises slowly (~1°C / second) then the glowplug and thermocouple circuits are operating correctly. The temperature will rise at a rate of at least 10°C / second if the flame lights. However, to prevent the fuel and air solenoids from remaining open in the event of the flame going out, the solenoids will only remain open if the temperature remains above a pre-set temperature (~120°C). If the START switch is released before the temperature reaches this cut off point, the solenoids will automatically shut, and the flame will extinguish. The start switch should not be held down for long periods as this shortens the life of the glowplug – it is better to make several attempts, holding the START switch down for 10-15 seconds at a time, than to hold the START switch down for one long period.

C.8 Purging the HSM fuel and air lines

The fuel and air lines to the HSM from the MCU must be purged when the HSM is lit for the first time after reconnection to the MCU. This is especially important if the HSM is connected to the MCU via EXT or EXT-Q extension cables, as the fuel line will take a long time to purge due to its extended length. If a new fuel supply is fitted, the supply line must also be purged safely.

To purge the lines, the user should attempt to light the FID in the normal way, remembering to hold down the START switch for periods of only 10-15 seconds at a time to avoid reducing the lifetime of the glow plug. Several attempts may be necessary to completely purge the fuel line – however the user will find that once this purging has been accomplished that the FID flame will light much more easily.

C.9 Contamination of FID chamber

Disassemble the sampling system of the HSM (instructions on how to do this are given in Section 7.4 of the HFR400 User Manual and also in the video supplement). If there is a large amount of oil or water collected in the base of the CP chamber and/or in the FID burner, it may make the flame difficult to light. For the FID to light, the FID and CP chambers must be cleaned of this liquid contaminant. Also see section C.16.

C.10 Tee-piece seals

The tee-piece seal which fits into the base of the FID burner is easy to over-tighten and may deform over time. The centre of the seal will creep up the base of the burner, and block the small holes that allow fuel to enter the burner. A faulty seal will have deformed as shown in Figure 10. If the seal has failed in this way, it must be replaced with a new seal. Instructions on how to do this are given in Section 7.4 of the HFR400 User Manual and also in the video supplement.

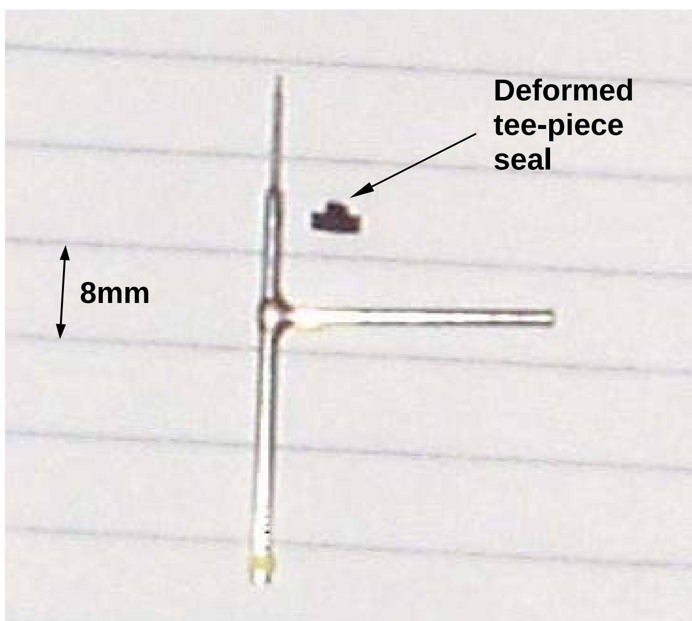


Figure 10

To tighten to the correct torque, tighten the grub-screw until the seal starts to compress then tighten the screw by turning it through a further 30°.

C.11 Burner o-ring seals

It is possible to misalign the large O-ring on the base of the FID burner when it is being inserted. This may result in damage to the O-ring, but usually results in a leak. Remove the O-ring and inspect it for damage (replacing it with a new one as necessary). To replace the burner without misalignment of the O-ring, the burner must have the o-ring place onto it (rather than into the base of the HSM). The burner can then be inserted vertically upwards into the base of the HSM. (See Figure 11). This ensures that the o-ring is correctly located as it is tightened.

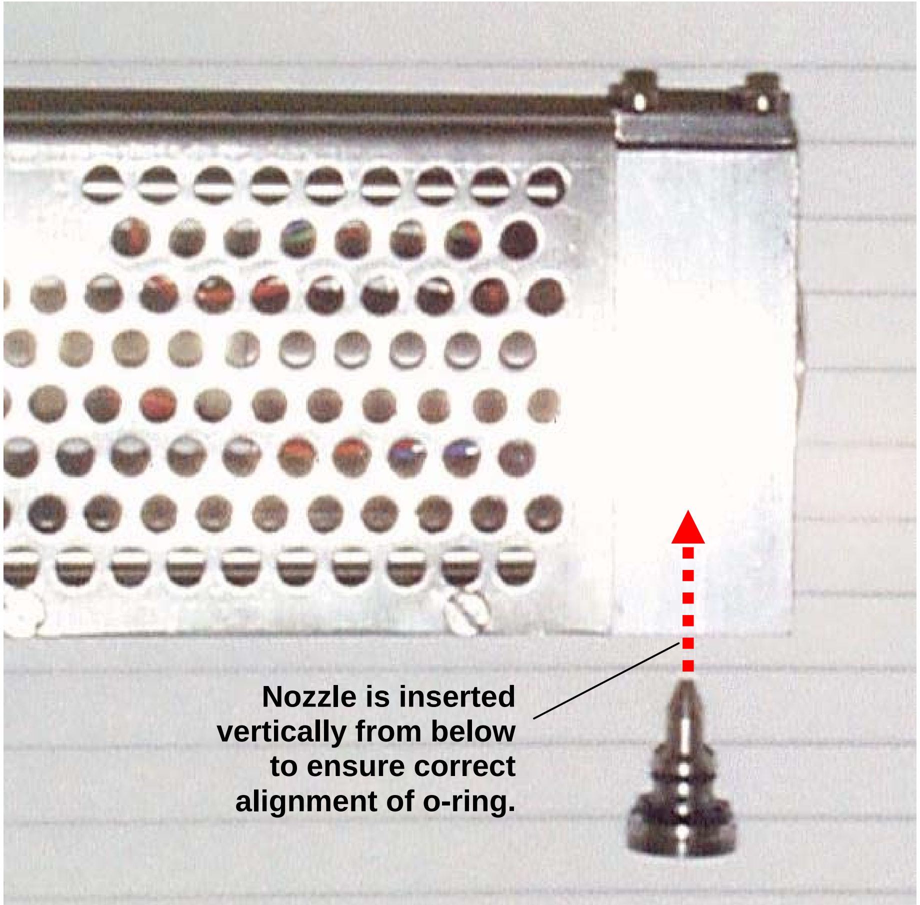


Figure 11

C.12 Glow-plug filament

Older HSMs may not have the filament of the glow plug protruding into the flame chamber. Removing the inspection hatch from the front of the HSM (Figure 13) enables the position of the filament to be checked. If the filament has not been drawn out of the glow plug body into the FID chamber, this can be accomplished by disconnecting the HSM and gently pulling the coiled filament with a pair of tweezers to a distance of 3mm from the glow plug body. Care should be taken that once extended, the filament is not touching any of the metalwork that surrounds it as this will cause the glow plug to fail.

C.13 HSM fuel and air restrictors

There are two small restrictors in the fuel and air lines at the rear of the HSM. These can be accessed by carefully cutting off the black heatshrink that surrounds them and pulling the restrictors out of the PTFE pipes. The restrictors can then be cleaned using the cleaning wires provided in the tool-kit. The fuel restrictor has an i/d of 0.008″ (0.2mm) and so can be cleaned with the tee-piece cleaning wire with the yellow colour-code. The air restrictor has an i/d of 0.016″ (0.4mm) and can be cleaned the blue colour-coded tee-piece cleaning wires.

C.14 Cleaning CP vacuum restrictor

The CP vacuum restrictor can be accessed by removing the black vacuum pipe from the rear of the CP chamber. The restrictor can then be cleaned with a large diameter cleaning wire.

C.15 Warm-up period of HSM

After lighting, the HSM should be left to warm up for at least 30 minutes. During this period, the output will drift down by about 10%. After this period, the output should be stable. Any residue left on the high voltage collector may also produce an offset immediately after lighting. However, moisture and light HC species will boil off during the warm-up period.

C.16 Cleaning the collector

If an offset persists, this may be due to an accumulation of oil or other material on the collector surface. The collector will probably be dirty if the inside of the flame chamber is coated with oil or water. Disconnect the sample head and remove the collector assembly (see the main manual). Clean with solvent (e.g. isopropyl alcohol) and replace. Be careful not to touch the metal parts of the collector when re-fitting.

The offset should diminish after the head warms up and residual cleaning fluid boils off. Ensure that the ZERO offset screw is correctly set (section B.15)

C.17 Overheating of collector

The collector can overheat if the fuel pressure is set too high. Check that the fuel pressure is no more than 2.5 bar.

With the HSM disconnected, remove the inspection hatch on the front of the HSM (see Figure 13). Check that the distance from the front face of the HSM to the button of the collector is approximately 12mm.

C.18 HSM vibration isolation

If the HSM is mounted to a vibrating support, the vibration frequency may appear on the FID signal. The HSM should be mounted separate to the engine on a stable support (e.g. camera tripod on stable ground).

C.19 Shielding HSM from a cooling airflow

The Fast FID is most stable when protected from large changes in ambient operating conditions. A common problem is cooling of the HSM from exhaust cooling fans and refrigeration units. If these are affecting the block temperature of the HSM, drift can occur. It is advisable to shield the HSM from cooling air flows.

C.20 FID thermocouple connection

With the HSM connected and a panel meter set to TEMP, an indication of the ambient temperature (+/- 5C) should be displayed. If ambient temperature is not displayed, disconnect the HSM and check the thermocouple connections in the HSM and LEMO connectors. Replace the thermocouple if necessary.

C.21 FID thermocouple position

The thermocouple should read the exhaust gas temperature of the HSM. The tip of the thermocouple should therefore be positioned in the centre of the exhaust pipe (and not touching the walls of the pipe or flame chamber).

Access to the thermocouple tip is via the FID chamber lid secured by 4 cap-head screws. Disconnect the HSM and adjust the tip position, if necessary, with long-nosed pliers.

C.22 Flame stabilising on glow-plug

Symptoms of this are high FID temperature and low signal output.

Switch off the flame and check fuel and air pressures are correct before re-lighting.

Appendix D DCS check procedures

D.1 DCS operation overview

The Dynamic Calibration System (DCS) ducts purge, zero and up to two span gases to the tip of the sample probe while the probe is located in the engine. In this way, the Fast FID signal can be checked for pressure independence by calibrating with the engine running and thus subjecting the calibration gas to the same pressure fluctuations as the sample gas. If the user obtains a flat calibration signal, there is no influence of sample pressure on the signal.

A small bypass gas flow is provided on **SAMPLE** to avoid static gas in the calibration fitting slowing the response time.

Sufficient flows of span, zero and purge must be set at the DCS to exclude all exhaust gas.

D.2 DCS gas pressure settings

A useful starting point for DCS pressure settings is 2 bar. This is usually sufficient to exclude all exhaust gas from the sample probe when the engine is running.

The pressures of span, zero and purge gas supplied by the DCS can be adjusted independently for each channel by adjusting the regulator on the front of the DCS for that channel.

D.3 Setting DCS to SPAN A /SPAN B / ZERO / SAMPLE / PURGE

The pressure gauge will indicate the supply pressure when gas is selected, and will return to zero when **SAMPLE** is selected.

If the pressure gauge does not rise when a gas is selected, check that the gas supplies to the DCS are turned on and that the regulator has been set correctly.

D.4 Check calibration level is flat

When the DCS is switched between gases or set to **SAMPLE**, the operator should wait for a few seconds for the gases to purge through the system, and for the signal to stabilise.

D.4.1 With engine running

After a few seconds, the span signal should be flat. If it is not, there may be insufficient span flow to exclude all of the exhaust gas from the TSL-H probe tip. Ensure that the span pressure is at least 2 bar. Check that with the zero gas set to 2 bar, there is a level zero trace without contamination of exhaust gas.

If 2 bar is insufficient to exclude all the exhaust gas, increase the pressures accordingly.

If the trace is still not flat, go to section D.4.2.

D.4.2 With engine stopped

Stop the engine and check for a level calibration signal.

If the calibration signal is still uneven, the dynamic pressure is not causing the problem. Check through section D.4.3.

D.4.3 Outside engine

If the calibration is still uneven, go to the COMMON PROBLEMS section entitled NOISY SIGNAL and work through the remaining questions.

Appendix E LHC check procedures

E.1 LHC operation

The Line Heater Controller (LHC) maintains the TSL-H sample probes at approximately 150C to prevent condensation of liquid fuel and water vapour contaminating the signals.

When the LHC and TSL-Hs are working properly, the **LINE TEMPERATURE** displayed on the panel meter, should be the same as the displayed **SET POINT** temperature. If this is not the case, check through the following points:

E.2 LHC MCB fault LED

The miniature circuitbreaker may not be closed. Check that the MCB switches on the LHC back panel have no red marker showing. They are then closed and ready to operate. If the MCB continues to trip, disconnect the LHC from mains electricity and CONTACT CAMBUSTION FOR ADVICE.

E.3 LHC status LED

The **STATUS** LED glows green when the TSL-H is being controlled correctly at its set point. It will glow orange when below temperature and glow red when over temperature.

If the **STATUS** LED is not green, substitute the TSL-H for a spare and CONTACT CAMBUSTION for repair advice.

E.4 LHC thermocouple fault LED

If the thermocouple is disconnected, the **FAULT** LED will illuminate. Ensure that the thermocouple connector is fitted in the front panel.

If the **FAULT** LED is still red, CONTACT CAMBUSTION for repair advice.

E.5 LHC power connections

Ensure that the black and red electrical push-fit connections from the LHC cable to the LHC are fitted correctly.

Appendix F TSL-H check procedures

F.1 Sample flow into HSM

With the HSM lit sampling atmospheric air, admit butane into the tip of the TSL-H from a unlit butane gas lighter. A definite signal increase should be evident. This shows that there is some flow through the TSL-H. If no signal is seen, see section F.2.

With the HSM lit and sampling zero air, hold the unlit butane gas lighter up to the **TEST** port on the front of the MCU and select **OUTPUT** on the panel meter. The output should remain at 0.00V.

If the output rises, the TSL-H may be blocked. See section F.2.

F.2 Cleaning the TSL-H

Switch off the TSL-H at the LHC and allow to cool for 5 minutes. Remove the TSL-H from the HSM.

Take a cleaning wire from the tool kit (0.022" for exhaust applications using a 0.026" TSL-H sampling probe) and push the cleaning wire through the TSL-H.

F.3 TSL-H temperature during operation

F.3.1 During switching on

The **LINE TEMPERATURE** should rise rapidly to the set point within 10 seconds. If the line temperature does not rise, check Appendix E.

F.3.2 On reaching set point

The **LINE TEMPERATURE** should remain stable at the set point during operation. An unstable temperature is normally accompanied by status and fault lights flickering.

Substitute a spare TSL-H and CONTACT CAMBUSTION for repair advice.

F.4 Broken TSL-H capillary

With the HSM lit and sampling zero air and **OUTPUT** selected on the panel meter, move the unlit butane gas lighter along the flexible part of the TSL-H and against the junction box. The level of 0.00V will rise if the TSL-H probe capillary is broken.

Substitute a spare TSL-H and CONTACT CAMBUSTION for repair advice.

F.5 TSL-H LEMO connection

Substitute in turn spare TSL-H and LHC cables to isolate any problems within LEMO connectors.

CONTACT CAMBUSTION for repair advice.

F.6 TSL-H connection to HSM

With the HSM lit and sampling zero air and **OUTPUT** selected on the panel meter, hold the unlit butane gas lighter at the TSL-H screw fitting onto the HSM. The level of 0.00V will rise if the seal is broken or loose.

Check the seal by disassembling the TNC screw connector and replace if necessary, ensuring that the connection is finger tight (see Figure 12), also check that the inlet of the tee-piece is not obscured by debris from a damaged seal.

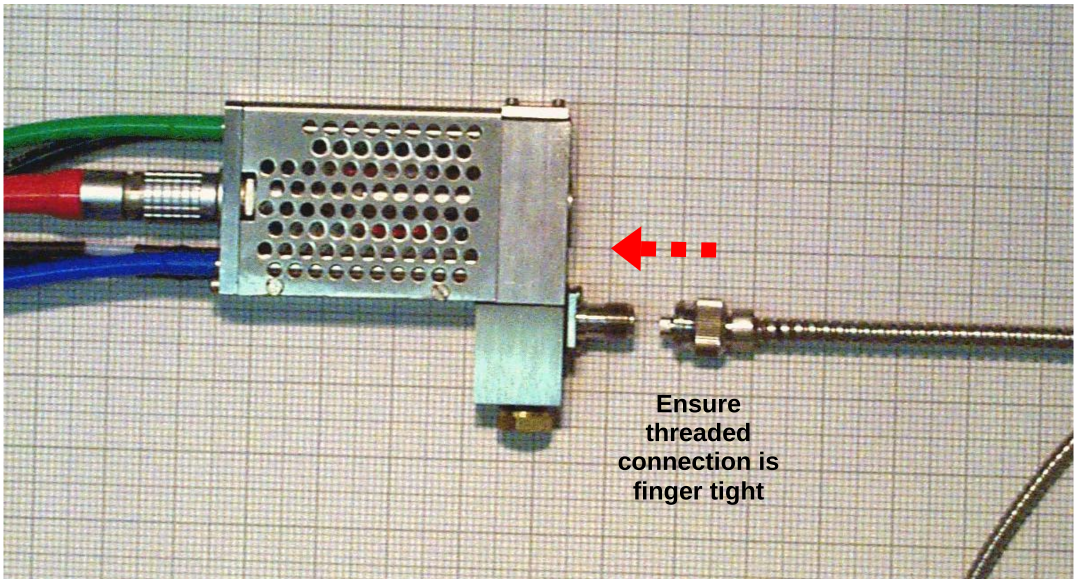


Figure 12

F.7 Noise from TSL-H

If a noisy span signal exists, switch off the LHC power to that channel and check if the noise remains. If the noise persists, substitute a spare TSL-H and CONTACT CAMBUSTION for repair advice.

F.8 Leaving the TSL-H connected to the engine

If the engine must be run for long periods but Fast FID data is not required, it is important to avoid filling the sample head HSM with exhaust gas as this will cause blockages and offset problems.

To avoid this, either:

- supply purge gas to the tip of the sample probe via the DCS to exclude exhaust gas for short duration tests

or

- remove the TSL-H and CAL-APT from the engine and plug the engine exhaust access hole

or

- unscrew the TSL-H from the HSM to protect the HSM from filling with condensate

To remove accumulated water effects see sections C.16 and C.9.

Appendix G General check procedures

G.1 Noisy ground connections

Ensure that all instrumentation and the engine are properly electrically grounded. Ground-loop problems tend to cause drift and offset problems.

Appendix H Exploded views of HSM and TSL-H

H.1 Exploded view of HSM

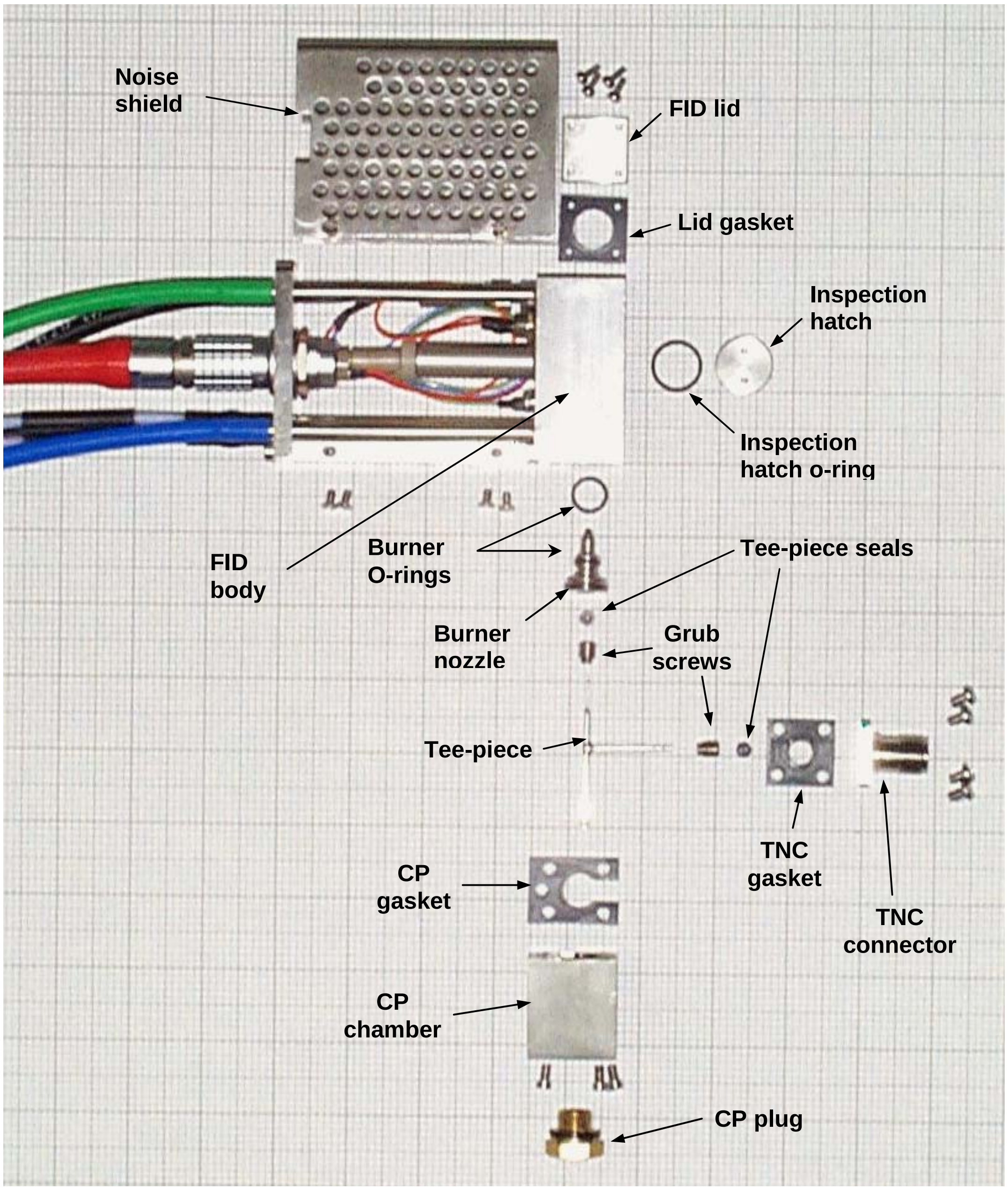


Figure 13

Figure 13 shows an exploded view of the HSM. The main user-serviceable parts are labelled.

H.2 Exploded view of TSL-H connector

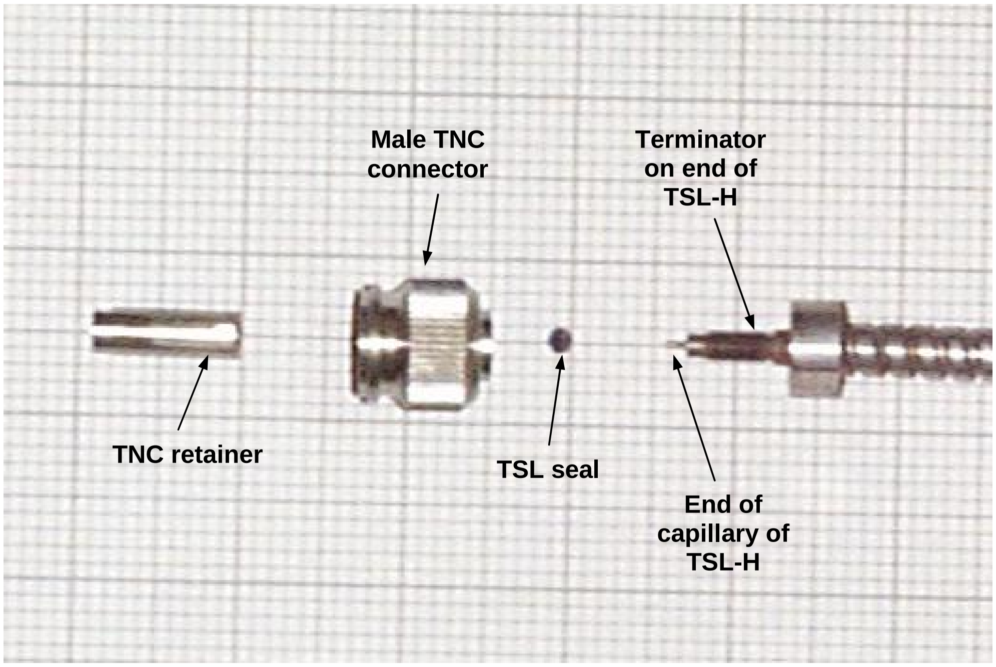


Figure 14

The TSL seal is located on the end of the capillary of the TSL-H which is connected to the HSM using the TNC connector. Figure 14 shows an exploded view of the connector at the end of the TSL-H, and the capillary onto which the TSL seal is fitted.