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MEC-PM-798-A
MEC Starter Kit Manual

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Reviewed by.....

Approved by.....

.....

.....

Date…… 9 April 2021

CONTENTS

1 REVISION HISTORY

Version	Name	Date	Comments
A	B. Westerdijk	9 April 2021	Change document name & number (from TM-744) Cover all engine-types Update for Control Box with LCD

1.1 Abbreviations

AC Alternating Current
BC (Hardware) Blocking Chain
DC Direct Current
LCD Liquid Cristal Display
MEC Microgen Engine Corporation (brand)
PCBA Printed Circuit Board Assembly
SW SoftWare
TDSP Thermo Dynamic Solution Provider B.V.
USA United States of America
VI Voltage and current(I) (monitoring)
WCS Water Cooled Seal

2 INTRODUCTION

TDSP provides MEC Starter Kits that make the first-time integration of a Stirling Engine in a customer's Application quite easy. A Starter Kit consists of a Stirling Engine, a Controls Box, and several other parts, as indicated on the provided quotation document. The Control Box is prewired to connect to the Engine and its provided internal and externally mounted sensors. This document provides information on connecting the Box to a heating system with a Stirling Engine. Also, information about how to run, control and troubleshoot such a system, is provided.

TDSP can provide Stirling Engines with the following Engine-head variants:

Finned Gas Head	Round Biomass Head	Bullet Biomass Head	Diamond Biomass Head	Solar Head

Figure 2.1 Available Engine-head-type options

The Biomass and Solar Engines weigh around 60 kg, and around 70kg when packaged and should be lifted and handled in accordance with any local handling requirements. A Gas Engine weighs 10kg less.

Ceramic collar: to prevent excessive heat loss from the burner it is necessary to provide thermal insulation between the heated area and the burner seal plate. This function is provided by the ceramic collars that are mounted on all MEC Stirling Engines.
CAUTION: Once the engine has been fired, the ceramic collars are potentially hazardous. See the Engine manual PS-V1-01 for details.

3 INSTALLATION

To be able to operate and generate electrical power, the Stirling Engine must be heated, cooled, and connected to an electrical AC-grid. This can be the local available 230VAC 50Hz or the 240VAC 60Hz single-phase state- or national-grid, or a locally generated 230V-50Hz/240V-60Hz single-phase AC-grid provided from a bi-directional inverter-charger set-up with batteries. Specifically, related to split-phase systems as available in e.g., the USA, to receive proper powering, the Engine must be connected across the two hot wires.
PLEASE NOTE: the MEC Stirling Engine can only act as a "grid-slave", it is not able act as a "grid-master", as a stand-alone generator.

An overview of a typical Engine installation is shown in fig. 3.1 on the next page.

The mechanical aspects related to the installation are:

- Heating of the Engine-head and heat-protection of the rest of the Engine and Application: the application of heat must be limited to the Engine-head only. As an option, the heating of the head should be mechanically regulated, to avoid overheating, or be completely removed in an emergency-stop-situation.
- The coolant-flow: the engine must be cooled sufficiently. The connections to the engine must be made through flexible hoses and the burner seal plate (when used) can be sealed via a flexible connection such as a polymer seal (note: there may be a temperature protection requirement).
- Mounting of the Engine: it can be mounted standing or hanging (option: up-side-down). Horizontal mounting or mounting under any angle is also possible. A bracket must be used to minimize vibrations. Approved mounting materials are available via TDSP.

The electrical part of the installation and the use of the provided Controls Box is described in detail in Chapters 4 and 5.

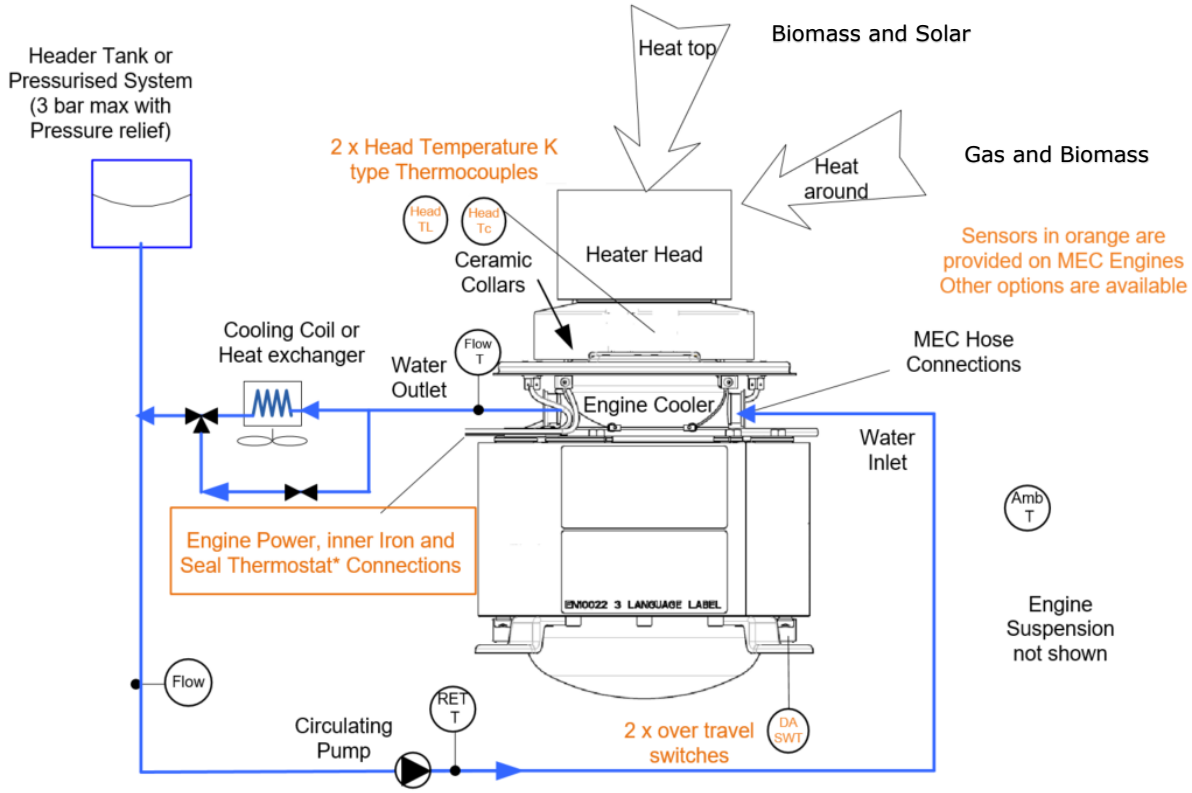


Figure 3.1 Engine Installation Schematic

The Stirling Engine comes with the following built-in sensors:

- K-type thermocouple for measuring the head-temperature, 2 pcs
- Inner-iron thermostat, 1 pc
- Over-travel switch, 2 pcs
- Water-Cooled Seal thermostat, 2 pcs

The following sensors are provided separately or connected to the Control Box wiring:

- Coolant flow temperature sensors for pipe-mounting, 2 pcs
- Coolant flow meter, 1 pc
- Ambient temperature sensor (inside the Controls Box)

4 STIRLING ENGINE ELECTRICAL CONNECTIONS

A simple schematic of the electrical connections to the Stirling Engine is shown below:

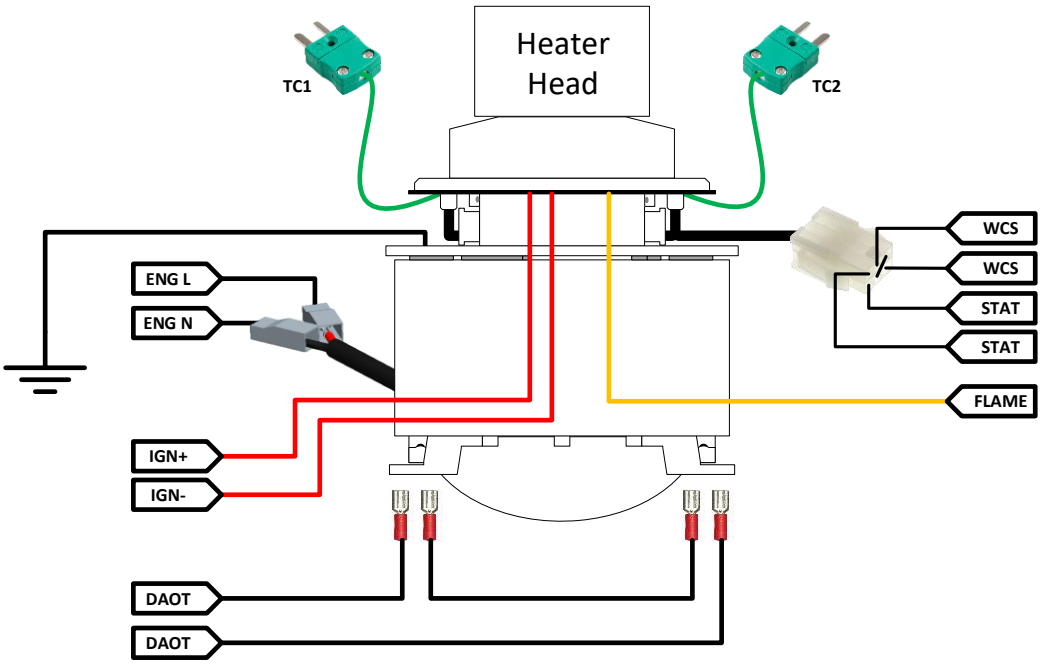


Figure 4.1 Engine electrical connections

TC1, TC2 : Engine head thermocouples connections,

ENG L, N : Engine AC power cable connections, locking-type connectors are required,

IGN +, - : Ignition probe connections, IGN - must be connected to GND,

DAOT : Dynamic Absorber Over-Travel switch connections,

WCS, STAT : Water Cooled Seal (mounted on the engine plate), Inner Engine thermostat connections,

FLAME : Flame detection (ionization) probe connection.

5 CONTROLS BOX ELECTRICAL CONNECTIONS

The Controls Box comes with the following cables/wires and connectors:

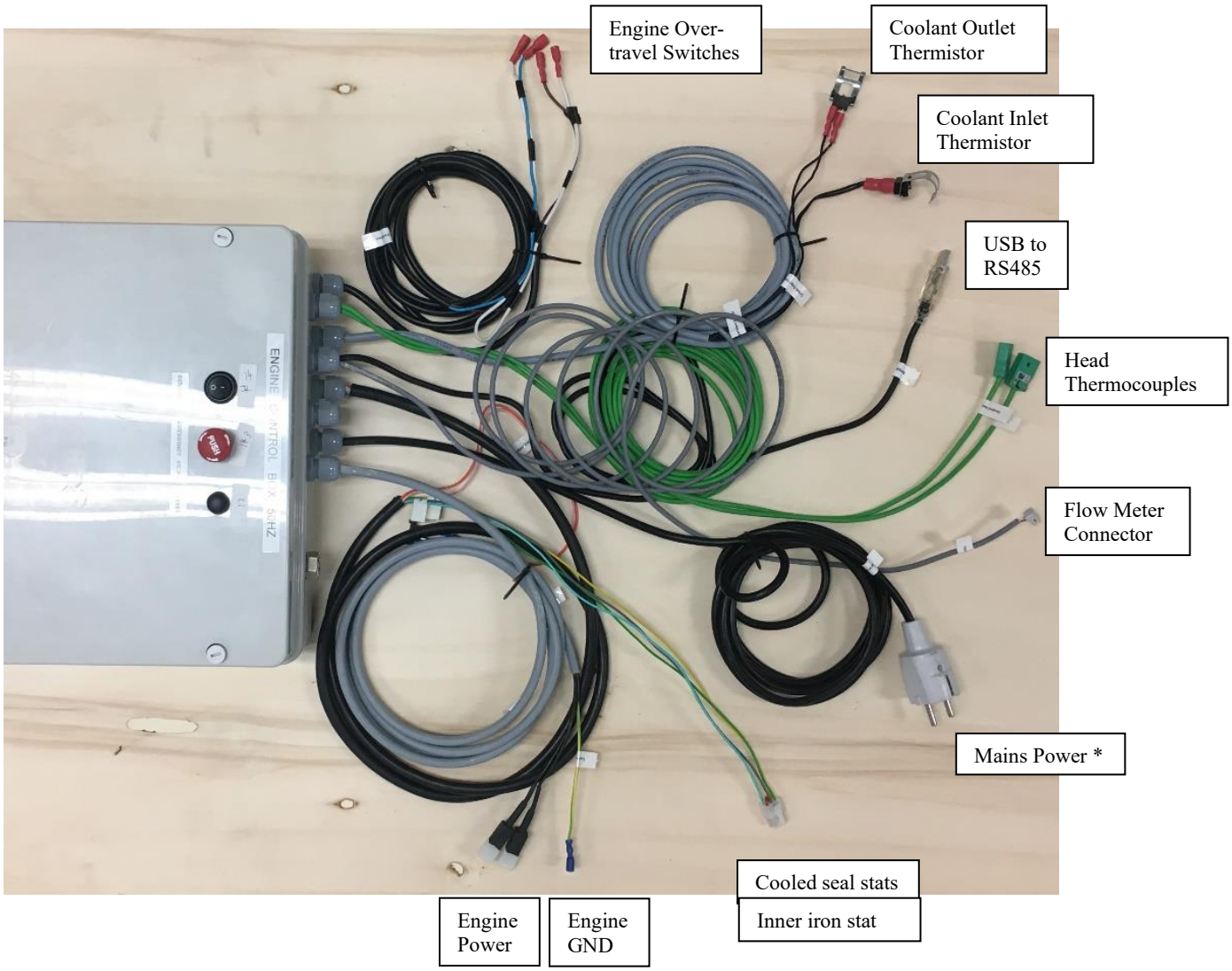


Figure 5.1 Control Box electrical connections

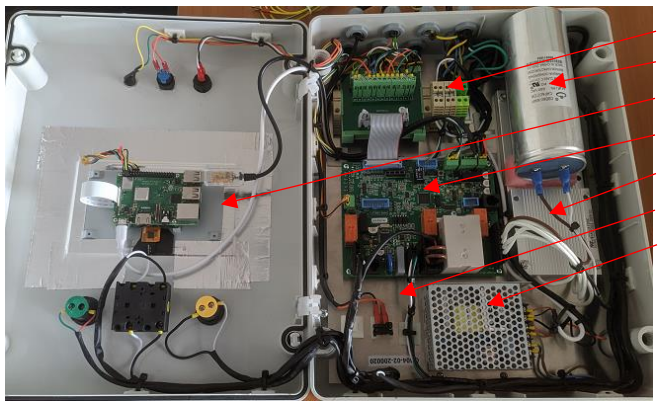
- The mains power connection must be hard-wired in accordance with local regulations.
- The ambient temperature thermistor is located inside the enclosure.

The front panel of the Controls Box has the following indicators and buttons:

1. User Reset button
2. Emergency Stop button
3. Demand on/off switch
4. LCD
5. Heat Enable Signal active indicator
6. Mains On/Off switch/isolator
7. Engine Running indicator

Figure 5.2 Control Box front panel

On this inside of the Box, the following parts can be seen:



1. Terminal block connectors
2. Engine Capacitor
3. Raspberry Pi and LCD
4. MEC Engine Control board
5. Start and Stop resistors
6. Ambient thermistor
7. 24V/5V PSU (Power supply)

Figure 5.3 Control Box internals

5.1 Controls Box connections shown in fig.5.1 explained

5.1.1 Absorber Over-Travel Switches

Connect the four connectors present on this cable onto the two Absorber Over-Travel switches that are incorporated into the Engine: when the Engine over-travels this will be detected immediately, and the Engine will be emergency-stopped.

5.1.2 Coolant in- and outlet thermistors

The coolant temperature sensors are already connected onto the cable, the clips fit onto a pipe with and outer diameter of 22mm.

5.1.3 RS485 Communications interface

This cable is provided to enable the use of the STIRLING ENGINE DATA VIEWER software:

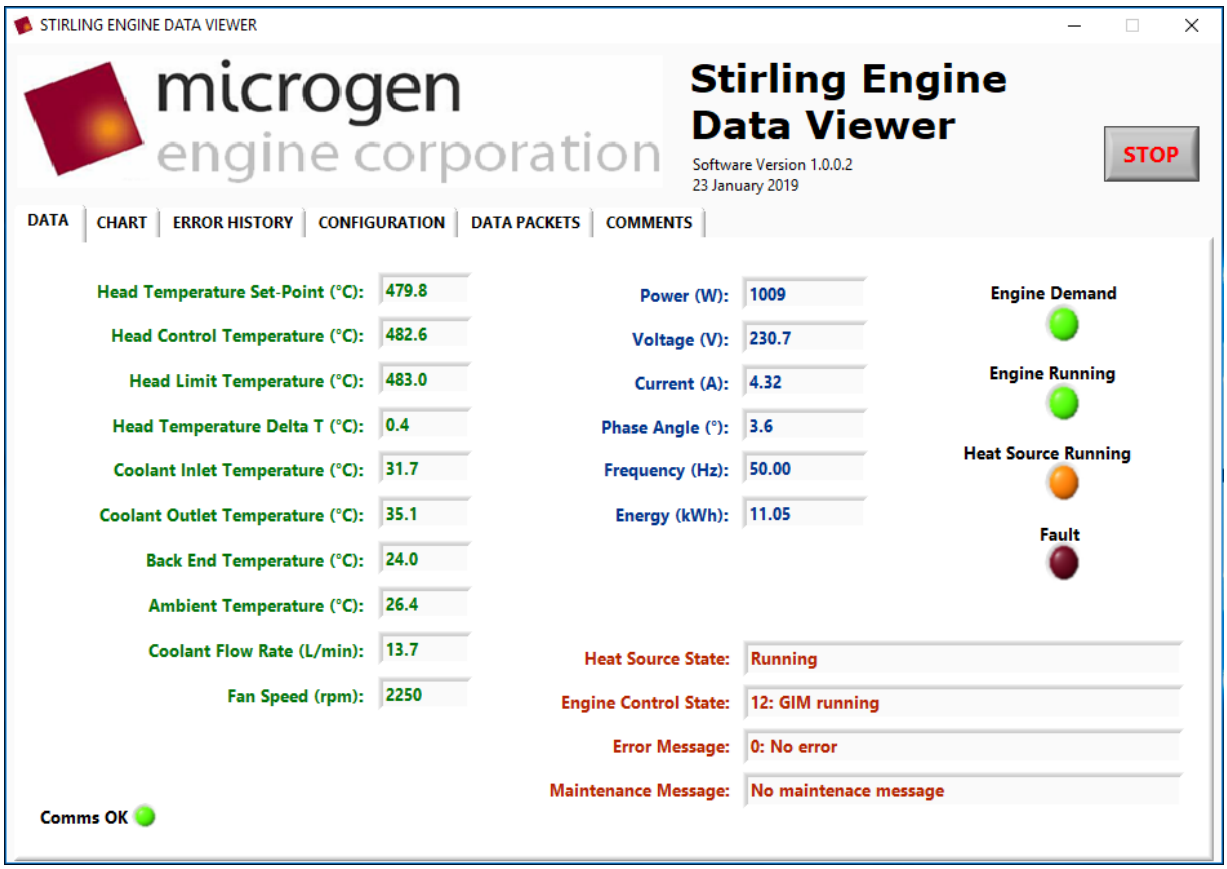


Figure 5.4 STRILING ENGINE DATA VIEWER

For details, please consult the Data Viewer User Manual MEC-WI-584.

Additionally, via the RS485 communication-bus, data can be provided to your Application which can be used to help control the heat source in running the Engine optimally and safe. Please contact TDSP for more information.

5.1.4 Head Thermocouples

Connect these two cables with connector to the two mating connectors of the two K-type thermocouples that are incorporated into the engine head. The values provided by these thermocouples are used as part of the Engine control and protection algorithms.

5.1.5 Flow Meter

Connect this cable with connector to the provided HUBA 200.915101N (DN15) vortex flow sensor, this sensor must be used to allow for measuring the coolant flow-rate.

5.1.6 Mains Power

Connect this cable with connector to a 230/240VAC power socket or remove the connector and connect the wires to the AC-out connector of an off-grid grid-building inverter-charger-battery system.

5.1.7 Cooled Seal and Inner Iron Protection Thermostats

Connect this cable with 6-way Molex connector to the matching connector on the Engine.
The inner Iron and cooled seal thermostats are not always used and may be linked out.

The Water Cooled Seal protection thermostats are, when present, located on the bottom of the engine burner seal plate. These thermostats will inhibit engine-operation when the temperature of the engine seal plate becomes too high.

The Inner iron thermostat is mounted inside the engine, it will inhibit engine-operation when the internal temperature becomes too high.

5.1.8 Grounding

The Engine must be grounded, connect the provided Green/Yellow insulated wire with ring to the engine flange using an M6 x 12 bolt and a star washer.

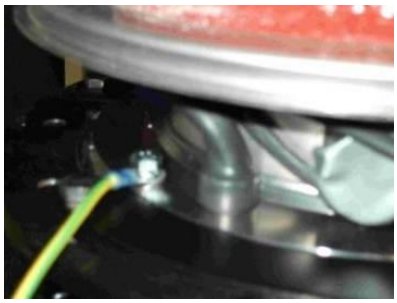


Figure 5.5 Engine Protective GND Connection

5.1.9 Engine Power

Connect the cable with the self-locking FASTON-connectors to the Engine Power cable.

5.2 Controls Box functions explained

5.2.1 Demand On/Off button and Heat Source Enable Indicator

The Demand input to the MEC Engine Control board is, as a default, provided via a mechanical on/off switch, providing ON-OFF operation of the system with Stirling Engine. The Heat Source Enable-switch on the Engine Control board is, as a default, hard wired to the yellow Heat Source Enable indicator light.

To automate the operation of the Engine as part of your Application, it is strongly recommended to route the control of the heat-source in your Application via the MEC Engine Control Board. By doing this the Engine will be able to operate optimally and safe. Please contact TDSP for more information when you are interested in this feature.

5.2.2 Emergency Stop Button

The Emergency Stop button/switch can be used to perform an emergency-stop of the Engine. Use only when absolutely needed, in case of an emergency!

5.2.3 User Reset Button

The User Reset button/switch can be used to perform a reset, see chapter 7.2 for more information.

5.2.4 Mains On/Off Switch

The Mains On/Off switch can be used to switch the Control Box on and off. Do not turn the switch to the off-position when the Stirling Engine is on operation, this will emergency-stop the Engine.

5.2.5 Engine Running Indicator

The green Engine Running indicator will light when the Stirling is in operation.

6 OUTLINE OF OPERATING SEQUENCE

[1] Once correctly assembled, plug the power-cable into a 230/240VAC power-socket (powered from the national grid) or connect it to the AC-out-port of a grid-building inverter-charger-battery system. Power on the Engine-system via the Mains On/Off-switch on the front panel of the Control Box.

[2] When the LCD is present on the Control Box, wait for the LCD to display the systems status. This can take up to 90 seconds.
When the LCD is not present, it is strongly recommended to have the STIRLING DATA VIEWER in operation and the laptop/computer it runs on connected to the Controls Box*.

[3] Turn the Demand switch to position "1" on the front panel of the Control Box.

[4] When no errors are showing on the LCD/DATA VIEWER or on the Engine Control board** the Heat Source Enable indicator will light***. This indicator lighting up means that it is OK to start heating the Engine-head.

[5] Once the head has heated to about 180°C (gas) / 220°C (biomass/solar), the Engine Control board will grid-connect and start the Engine.

[6] When a fault or an issue occurs, the Engine Control board will turn off the Heat Source Enable indicator and depending on the nature of the fault will emergency stop the engine within 100ms or will allow the engine to run down to zero power, then automatically disconnect the Engine from the grid, a normal stop. **Please make sure to quickly stop the heating of the head when this happens!**

[7] Pressing the User Reset button for 2 seconds will reset errors on the Engine Control board which require a manual reset. Please use it with care, only push this button when indicated in the Maintenance Message-field on the LCD/DATA VIEWER.

[8] A normal shutdown of the system is initiated by first stopping the heating of the head and switching the Demand switch to position "0". The Engine Control board will allow the engine to run down, cool off and be ready to start again. A hot engine cannot be restarted until the head temperatures are below the grid connection temperature (< 170/210°C).

[9] In case manual movement or servicing of the Engine is required, it can be performed, once the Engine-head temperature has dropped below 50°C.

* The RS485 communication-link can be used to display and log the Engine system parameters and functions via the MEC Data Viewer software. This Viewer shows the system's status, engine power and head temperature data, which can assist in the manual control of the heat source.

** On error or fault, a small red light will show on the Engine Control board and an error (with code) will be displayed on the LCD/DATA VIEWER.

*** It is recommended to hard-wire the heat source enable signal to control the heat source, see chapter 5.2.1.

7 ERRORS

7.1 Error Code List

Code	Description	AR	UR	NStop	EStop
10	Inlet temperature sensor short-circuit	x		x	
11	Inlet temperature sensor open-circuit	x		x	
12	Outlet temperature sensor short-circuit	x			
13	Outlet temperature sensor open-circuit	x			
14	Backend temperature sensor short-circuit	x			
15	Backend temperature sensor open-circuit	x			
16	Ambient temperature sensor short-circuit	x			
17	Ambient temperature sensor open-circuit	x			
18	PCBA under- or over-temperature	x		x	
101	Configuration error		x		x
301	Inner iron over-temperature	x			x
303	Dynamic absorber over-travel		x		x
304	Grid protection	x			x
306	Alternator overload		x		x
309	VI protection trip	x			x
310	Head over-temperature HW		x	x	
311	Head under-temperature HW	x			x
312	WCS thermostat trip	x			x
325	Unidentified BC trip	x			x
404	Head under-temperature SW		x		x
405	Head over-temperature SW	x		x	
406	Head temperature measurement discrepancy		x	x	
407	Control thermocouple failure		x		x
408	Limit thermocouple failure		x		x
411	Under-current		x		x
414	Resistor integrity check failure		x		x
415	24 VDC power supply failure	x			x
420	Control thermocouple open-circuit	x			x
421	Limit thermocouple open-circuit	x			x
422	Control thermocouple integrity check failure	x			x
423	Limit thermocouple integrity check failure	x			x
424	Coolant over-temperature	x		x	
425	Coolant under-temperature	x		x	

Key: *AR = Automatic reset, UR = User Reset*
NStop = Normal stop (i.e. Heat source disabled)
EStop = Emergency-stop (i.e. Heat source disabled and engine stopped)

Code	Description	AR	UR	NStop	EStop
501	Power meter comms checksum failure	x			x
502	Power meter comms timeout	x			x
504	VI protection reset	x			x
505	VI protection under-voltage trip	x			x
506	VI protection under-voltage trip	x			x
507	VI protection under-voltage trip	x			x
508	VI protection over-voltage trip	x			x
509	VI protection over-voltage trip	x			x
510	VI protection over-voltage trip	x			x
511	VI protection under-frequency trip	x			x
512	VI protection over-frequency trip	x			x
513	VI protection short-circuit trip	x			x
514	VI protection trip	x			x
603	Low coolant flow rate	x		x	
604	Ambient over-temperature	x		x	
605	Reset switch fault		x	x	
610	Zero coolant flow rate	x			x

Key: *AR = Automatic reset, UR = User Reset*
NStop = Normal stop (i.e. Heat source disabled)
EStop = Emergency-stop (i.e. Heat source disabled and engine stopped)

7.2 Clearing Errors

There are two levels of error severity.

Severity Level	**Reset Method**
1	Automatic reset
2	User Reset

7.2.1 Automatic Reset

Errors that are less severe will be reset automatically. Normally, no manual intervention is required for this type of error conditions. However, in some cases manual intervention may be required. For instance, in the case of a faulty sensor, the error condition will reset automatically but only after the sensor has been repaired/replaced.

7.2.2 User Reset

When a more serious error occurs, faults that could lead to engine damage, a physical/electrical check and repair-action might be required. Such errors can only be cleared by a User Reset. A User Reset can be performed by closing a normally-open

volt-free contact for minimum of 1 to maximum 6 seconds. A switch, directly available to the user, can be mounted in/on the Application. Alternatively, the User Reset can be handled via the external communications interface.

7.3 Troubleshooting an error

Please see Appendix B to troubleshoot errors.

8 DIAGNOSTICS

8.1 Engine Control States

The current operating state of the engine is available via the RS485-bus for diagnostic purposes.

State Number	State Name	State Description
0	Stopped	Engine stopped. Waiting for demand or fault reset.
1	Head	Waiting for head temperature to reach grid connection temperature.
2	Mains	Grid connection in progress.
3	Bypass	Bypassing start resistors.
4	Mains Close	Disconnect start resistors from circuit.
5	Running	Engine running directly grid connected.
6	Overrun	Engine stopped and waiting for the head temperature to cool down. Heat source disabled.
7	Shutdown	Heat source disabled. Engine running down, waiting for the engine to stop normal.
8	Emergency	Engine emergency-stopped. Heat source disabled.

9 ENGINE SPECIFICATION, CONNECTIONS AND OPERATION

Head Temperature	525°C continuous, 565°C max.
Nominal Power output	1000W (model dependent)
Coolant Flow	4-7 l/min short term, > 7 l/min continuous
Coolant Circuit pressure	1.8 Bar min. to 3 Bar max.
Maximum coolant Inlet temperature	70-75°C short term, < 70°C continuous
Minimum coolant temperature	6°C, contact TDSP for starting at lower temps

APPENDIX A LCD DATA MONITOR – USER MANUAL

Operating Instructions

The LCD Data Monitor device will automatically power up at power-on of the Controls Box. It can take up to 90 seconds before the screen is available and is showing data.

On the screen, in the bottom-area there are 3 buttons, see figure B.1. The left button is the Home-button, showing the status of the Stirling Engine and the various sensors, of the burner (when the heat source running input is connected), and of the control system input (Demand).
The middle button is the Data-button, the corresponding screen shows various detailed sensor- and system-data.
The right button is the Info-button, the corresponding screen shows various info, including the firmware-versions stored in the EC2 board flash memories.

When an error occurs, there will be a red bar at the top of the screen with text describing the error. When an error has occurred and has automatically been resolved, there will be an orange bar showing "Last Error:" followed by the error-text. Both bars can be removed from the screen by pressing the Bin-icon on the right end of the bar. Please note: the red bar will reappear until the root-cause of the error has been removed.

The screen will turn off after some time, when not used. Touch the screen once to wake it up.

NOTE: under certain conditions there can be an error shown on the LCD: "No USB connected" while the internal USB-cable is connected. When this happens, please open the Controls Box, while powered on, ***careful, high voltage on some parts***, and pull out the internal USB-cable connected to the LCD Data Monitor (Raspberry Pi), wait a few seconds, and push it back in. Next, power off the Control Box, wait for about 10 seconds and power it on again. This should resolve the error. When this does not work, please contact TDSP BV for assistance.

Wi-Fi Access

The LCD Data Monitor device in its default state is set up as a Wi-Fi Access Point (AP) with the SSID: "MEC_Starter_Kit".

Connect to this Wi-Fi AP with your device with wireless capabilities: a computer, laptop, tablet, mobile phone, etc.

Please request the Wi-Fi password from your contact at TDSP.

When your device is connected to the AP, open a web browser and browse to http://microgen/ (non-Apple devices), http://microgen.local/ (Apple devices), or if that doesn't work to http://10.0.0.5/

You should now see the default page:

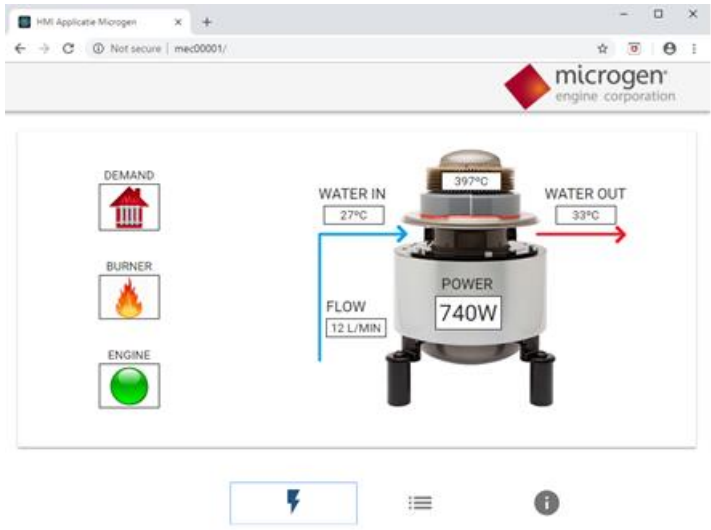


Figure B.1: Data Monitor default webpage

The additional pages can be accessed via the additional 2 buttons at the bottom of the screen.

Connect the LCD Data Monitor device to the local Wi-Fi network:

Connect your wireless capable device with a keyboard (physical or on-screen) to the AP as described above. **DO NOT perform** this task on the LCD-screen of the Data Monitor device.

Press the MICROGEN-logo 4 times, press the WIFI SETUP button.

A window will appear showing the available Wi-Fi APs (press the refresh button when needed).

A password-entry window will appear, enter the password, and press the SUBMIT-button. Now wait until a second message-window will appear. Read the message and press the OK button. All Wi-Fi-setup-related windows will close automatically, and your wireless capable device should automatically reconnect to the default local Wi-Fi AP.

Next, open a web browser on any device in your network and browse to http://microgen/ (non-Apple devices), http://microgen.local/ (Apple devices), or if that doesn't work to http://10.0.0.5/

You should now see the default page, see figure B.1.

NOTE: if anything goes wrong during the above-described process, or when you change the password of the local Wi-Fi AP, the LCD Data Monitor device will automatically return to its default state, providing the Wi-Fi AP with the SSID: "MEC_Starter_Kit".

APPENDIX B ERROR LIST

Fault Code	Description	Potential Causes	Actions to Take	Lockout/Reset Action
10	Coolant inlet temperature sensor short-circuit	Coolant inlet temperature sensor short-circuit.	Check coolant inlet sensor. Check the wiring between the coolant inlet sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:13 (REFERENCE) J12:14 (SIGNAL)	Normal Shutdown, Automatic Reset (5 seconds)
11	Coolant inlet temperature sensor open-circuit	Coolant inlet temperature sensor open-circuit.	Check coolant inlet sensor. Check the wiring between the coolant inlet sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:13 (REFERENCE) J12:14 (SIGNAL)	Normal Shutdown, Automatic Reset (5 seconds)
12	Coolant outlet temperature sensor short-circuit	Coolant outlet temperature sensor short-circuit.	Check coolant outlet sensor. Check the wiring between the coolant outlet sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:15 (REFERENCE) J12:16 (SIGNAL)	No action, Reported only
13	Coolant outlet temperature sensor open-circuit	Coolant outlet temperature sensor open-circuit.	Check coolant outlet sensor. Check the wiring between the coolant outlet sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:15 (REFERENCE) J12:16 (SIGNAL)	No action, Reported only
14	Back end temperature sensor short-circuit	Back end temperature sensor short-circuit.	Check back end sensor. Check the wiring between the back end sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:17 (REFERENCE) J12:18 (SIGNAL)	No action, Reported only
15	Back end temperature sensor open-circuit	Back end temperature sensor open-circuit.	Check back end sensor. Check the wiring between the back end sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:17 (REFERENCE) J12:18 (SIGNAL)	No action, Reported only

16	Ambient temperature sensor short-circuit	Ambient temperature sensor short-circuit.	Check ambient sensor. Check the wiring between the ambient sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:19 (REFERENCE) J12:20 (SIGNAL)	No action, Reported only
17	Ambient temperature sensor open-circuit	Ambient temperature sensor open-circuit.	Check ambient sensor. Check the wiring between the ambient sensor and the control system. Check sensor is fitted correctly. Sensor should be 10K NTC thermistor. Sensor connection to PCB: J12:19 (REFERENCE) J12:20 (SIGNAL)	No action, Reported only
18	PCB temperature protection	PCB over-temperature or under-temperature.	Check PCB temperature.	Normal Shutdown, Automatic Reset (30 seconds)
101	Configuration error	GIM/Grid jumpers incorrectly fitted. Incorrect software installed.	Check software version. Check GIM/Grid jumpers are fitted correctly.	Emergency Shutdown, Service Reset
301	Inner iron over-temperature	Inner iron over-temperature. Open-circuit in blocking chain.	Wait for thermostat to close, which may take several minutes. Spurious trip? Visually inspect wiring connections. Check continuity. Switch connection to PCB: J12:7 (REFERENCE) J12:8 (SIGNAL)	Emergency Shutdown, Automatic Reset (10 seconds)
303	Dynamic absorber over-travel	Dynamic absorber over-travel. Open-circuit in blocking chain.	Spurious trip? Visually inspect wiring connections. Check continuity. Switch connection to PCB: J12:6 (REFERENCE) J12:5 (SIGNAL)	Emergency Shutdown, Service Reset
304	G83/ENS protection	G83/ENS protection tripped. Open-circuit in blocking chain.	Check status of Grid-Protection module (info in manual). Visually inspect wiring connections. Check continuity. Switch connection to PCB: J12:1 (REFERENCE) J12:2 (SIGNAL)	Emergency Shutdown, Automatic Reset (3 minutes)
306	Alternator overload	Alternator overload. Open-circuit in blocking chain.	Visually inspect wiring connections. Check continuity. Switch connection to PCB: J12:11 (REFERENCE) J12:12 (SIGNAL)	Emergency Shutdown, Service Reset
309	VI protection trip	VI protection trip. Open-circuit in blocking chain. Trip generated by power meter IC.	Blocking chain switch on EC2 board. Possible PCB hardware fault.	Emergency Shutdown, Automatic Reset (3 minutes)

310	Head over-temperature	Head over-temperature. Open-circuit in blocking chain.	Check both head thermocouple measurements. Check for large temperature differences across the head. Visually inspect thermocouple connections.	Normal Shutdown, Service Reset
311	Head under-temperature	Head under-temperature. Open-circuit in blocking chain.	Check both head thermocouple measurements. If head temperature is cold, wait for head to warm up. Visually inspect thermocouple connections.	Emergency Shutdown, Automatic Reset (30 seconds)
312	Remote emergency stop	Remote emergency stop pressed. Open-circuit in blocking chain.	Visually inspect wiring connections. Check continuity. Switch connection to PCB: J12:9 (REFERENCE) J12:10 (SIGNAL)	Emergency Shutdown, Automatic Reset (10 seconds)
325	Intermittent break in the blocking chain	Open-circuit in blocking chain. Bad connection. Damaged wiring. Faulty switch.	Visually inspect wiring connections. Check continuity.	Emergency Shutdown, Automatic Reset (30 seconds)
404	Head under-temperature	Head under-temperature.	Check thermocouple measurements. Report to TDSP: provide logged data.	Emergency Shutdown, User Reset
405	Head over-temperature	Head over-temperature.	Check thermocouple measurements. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (3 minutes)
406	Head temperature measurement discrepancy	More than 100° difference between the two sensors.	Check the heat distribution of the heating source. Report to TDSP: provide logged data.	Normal Shutdown, User Reset
407	Control thermocouple failure	Unexpected large temperature change. Damaged thermocouple.	Check thermocouple operation. Report to TDSP: provide logged data.	Emergency Shutdown, User Reset
408	Limit thermocouple failure	Unexpected large temperature change. Damaged thermocouple.	Check thermocouple operation. Report to TDSP: provide logged data.	Emergency Shutdown, User Reset
411	Under-current	Under-current. Likely cause: no Live and/or Neutral connection between engine and control system.	Check continuity. Monitor performance during first minute of engine operation. Report to TDSP: provide logged data.	Emergency Shutdown, User Reset
413	Engine stall	Excessive load connected.	Check connected load(s).	Normal Shutdown, Automatic Reset (1 minute)
414	Resistor integrity check failure	Resistor integrity check failure.	Monitor performance during first few seconds of engine operation. Check GIM shorting links are properly fitted to EC2 board connector J3. Check for thermocouple measurement differences. Under-temperature protection may prevent grid connection. Check for large temperature differences across the head. Report to TDSP: provide logged data.	Emergency Shutdown, Service Reset
415	24 VDC power supply failure	24 VDC power supply failure.	24 VDC power supply problem. Check for external wiring faults.	Emergency Shutdown, Automatic Reset (3 minutes)

420	Control thermocouple open-/short-circuit	Thermocouple is open- or short-circuited.	Check thermocouple connection and polarity. Check thermocouple wiring. Is head very cold (less than 3 °C)? If yes, warm up the head.	Emergency Shutdown, Automatic Reset (5 seconds)
421	Limit thermocouple open-/short-circuit	Thermocouple is open- or short-circuited.	Check thermocouple connection and polarity. Check thermocouple wiring. Is head very cold (less than 3 °C)? If yes, warm up the head.	Emergency Shutdown, Automatic Reset (5 seconds)
422	Control thermocouple integrity check failure	Measured value not rising during first minute of burner firing.	Check thermocouple temperature rise during first minute of burner firing. Check thermocouple is properly located in thermal well. Report to TDSP: provide logged data.	Emergency Shutdown, Automatic Reset (20 minutes)
423	Limit thermocouple integrity check failure	Measured value not rising during first minute of burner firing.	Check thermocouple temperature rise during first minute of burner firing. Check thermocouple is properly located in thermal well. Report to TDSP: provide logged data.	Emergency Shutdown, Automatic Reset (20 minutes)
424	Coolant over-temperature	Coolant over-temperature.	Check coolant flow rate. Check coolant inlet temperature. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (5 seconds)
425	Coolant under-temperature	Coolant under-temperature.	Check coolant flow rate. Check coolant inlet temperature. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (5 seconds)
501	Power meter communications checksum failure	Power meter communications checksum failure.	Internal communication problem. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (3 minutes)
502	Power meter communications timeout	Power meter communications timeout.	Internal communication problem. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (3 minutes)
503	Power meter registration timeout	Power meter registration timeout.	Internal communication problem. Report to TDSP: provide logged data.	Normal Shutdown, Automatic Reset (3 minutes)
504	VI protection reset	VI protection microcontroller has reset.	Internal problem. Report to TDSP: provide logged data.	Emergency Shutdown, Automatic Reset (3 minutes)
505	Under-voltage trip	Grid voltage level is too low.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
506	Under-voltage trip	Grid voltage level is too low.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
507	Under-voltage trip	Grid voltage level is too low.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
508	Over-voltage trip	Grid voltage level is too high.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
509	Over-voltage trip	Grid voltage level is too high.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
510	Over-voltage trip	Grid voltage level is too high.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
511	Under-frequency trip	Grid frequency is too low.	Check grid frequency.	Emergency Shutdown, Automatic Reset (3 minutes)
512	Over-frequency trip	Grid frequency is too high.	Check grid frequency.	Emergency Shutdown, Automatic Reset (3 minutes)
513	Short-circuit trip	High current measurement.	Check engine current.	Emergency Shutdown, Automatic Reset (3 minutes)

514	VI protection trip	Grid voltage problem.	Check grid voltage.	Emergency Shutdown, Automatic Reset (3 minutes)
603	Low coolant flow rate	Low coolant flow rate.	Check coolant flow rate. Check coolant flow sensor. Check the wiring between the coolant flow sensor and the control system.	Normal Shutdown, Automatic Reset (30 seconds)
604	Ambient over-temperature	Ambient over-temperature.	Check the ambient temperature. Check the ambient temperature sensor. Check the wiring between the ambient temperature sensor and the control system.	Normal Shutdown, Automatic Reset (30 seconds)
605	Reset switch fault	There is a fault with the reset switch.	Check that a normally open contact on the switch is used for reset. Check that there are no short-circuits on the external switch connection.	Normal Shutdown, Service Reset
610	Zero coolant flow rate	No coolant flow.	Check coolant flow rate. Check coolant flow sensor. Check the wiring between the coolant flow sensor and the control system.	Emergency Shutdown, Automatic Reset (30 seconds)

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