SPECTRONIK

PROTIUM-375

ECO MARATHON PACKAGE

USER GUIDE

VERSION 2.1 JANUARY 2023

SAFETY, HANDLING & SUPPORT

WARNING: *Failure to follow these safety instructions could result in fire, electric shock, or other injuries, or damage to PROTIUM-375 Fuel Cell System (PROTIUM-375) or other property. Read all the safety information below before using PROTIUM-375.*

Handling Handle PROTIUM-375 with care. It is made of thin sheet metal, graphite, and plastic and has sensitive electrochemical membrane and components inside. PROTIUM-375 is not designed for extreme conditions, rough handling, vibration, shock or drop. Keep PROTIUM-375 away from heat, flame, strong sunlight, water, dust, soil or mud. Do not use a damaged PROTIUM-375.

Repairing PROTIUM-375 is assembled under high compression. Do not disassemble or tamper with PROTIUM-375. Do not troubleshoot, repair or replace any component by yourself.

Hydrogen Use only high purity (99.999%) dry Hydrogen gas with PROTIUM-375. Hydrogen is a colorless, odorless and highly flammable gas. It is non-toxic but can cause asphyxiation. Follow all local rules and regulations for safe handling, storage and usage of Hydrogen gas. Do not smoke when operating PROTIUM-375.

Ventilation Operate PROTIUM-375 in a well ventilated environment. Fresh air intake for the fuel cell oxidant blower, cooling air entry from the front of the protective mask, and hot air exit from the cooling fans shall not be obstructed or restricted.

Purging PROTIUM-375 periodically flushes its anode during operation, releasing Hydrogen gas and water from the Hydrogen gas outlet. Do not block the Hydrogen gas outlet. Do not bring flame or electric spark close to the Hydrogen gas outlet. It is advisable to attach a longer gas tubing to the Hydrogen gas outlet connector and safely guide the purge exhaust far away from the fuel cell.

CAUTION: Always put the Hydrogen gas outlet tubing behind the cooling fan and never in front of the fuel cell stack. Purged Hydrogen mixed with air intake into the fuel cell's cathode channels may cause fire and irreversible damage to the fuel cell.

Connectors, ports and buttons Never force a connector into a port or apply excessive pressure to a button. If the connector and port do not join with reasonable ease, they probably do not match. Check for obstructions and ensure that the connector matches the correct port.

Disposal and recycling As PROTIUM-375 contains electronic components, it must be disposed of separately from household waste. When PROTIUM-375 reaches its end of life, follow local laws and regulations for proper disposal and recycling options.

High-consequence activities PROTIUM-375 is a customized system with pending safety tests and certifications. It is not intended for use where the failure of the system could lead to death, personal injury or severe environmental damage.

Disclaimer Every effort has been made to ensure that the information in this manual is accurate. This manual serves to adequately recommend safe operating procedures, but shall not be treated as comprehensive. Do not use PROTIUM-375 in any other way than the one recommended in this manual. Spectronik reserves the right to change system specifications, appearance or discontinue the product at any time.

Warranty Spectronik warrants the included hardware product and accessories against defects in materials and workmanship for the first 30 days after delivery. Spectronik does not warrant against normal wear and tear, nor damage caused by accident or abuse.

To obtain service, contact support@spectronik.com

1 OVERVIEW

1.1 PROTIUM-375 SYSTEM OVERVIEW

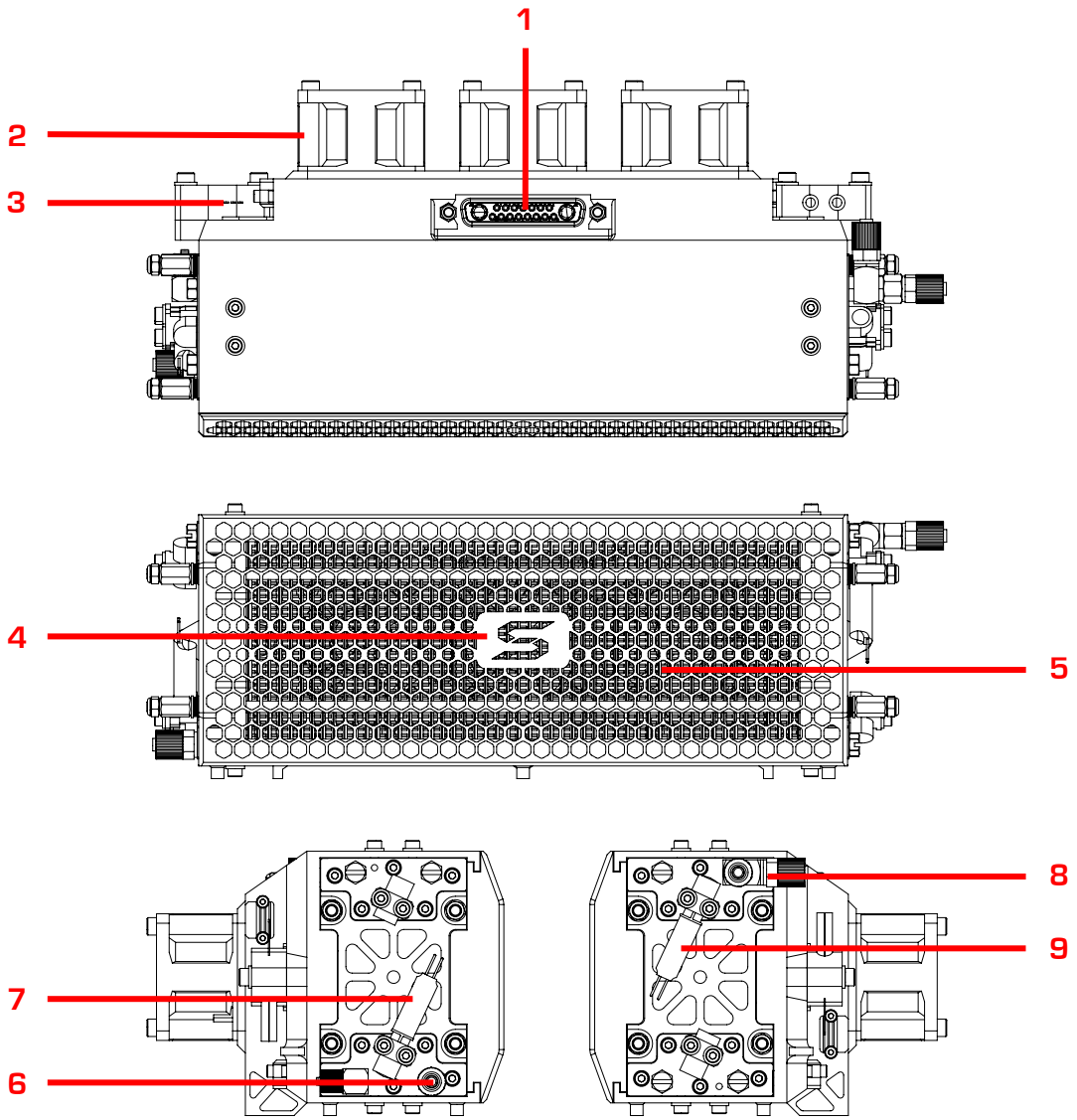


Figure 1.1.1 Top, Front, Left and Right views of PROTIUM-375

ITEM	DESCRIPTION
1.	Power/Signal receptacle
2.	Cooling fan (x3)
3.	Pressure sensor (x2)
4.	Protective mask
5.	Fuel cell stack
6.	H_2 gas outlet connector
7.	Gas purge solenoid valve
8.	H_2 gas inlet connector
9.	Gas supply solenoid valve

1.2 ELECTRONIC CONTROLLER

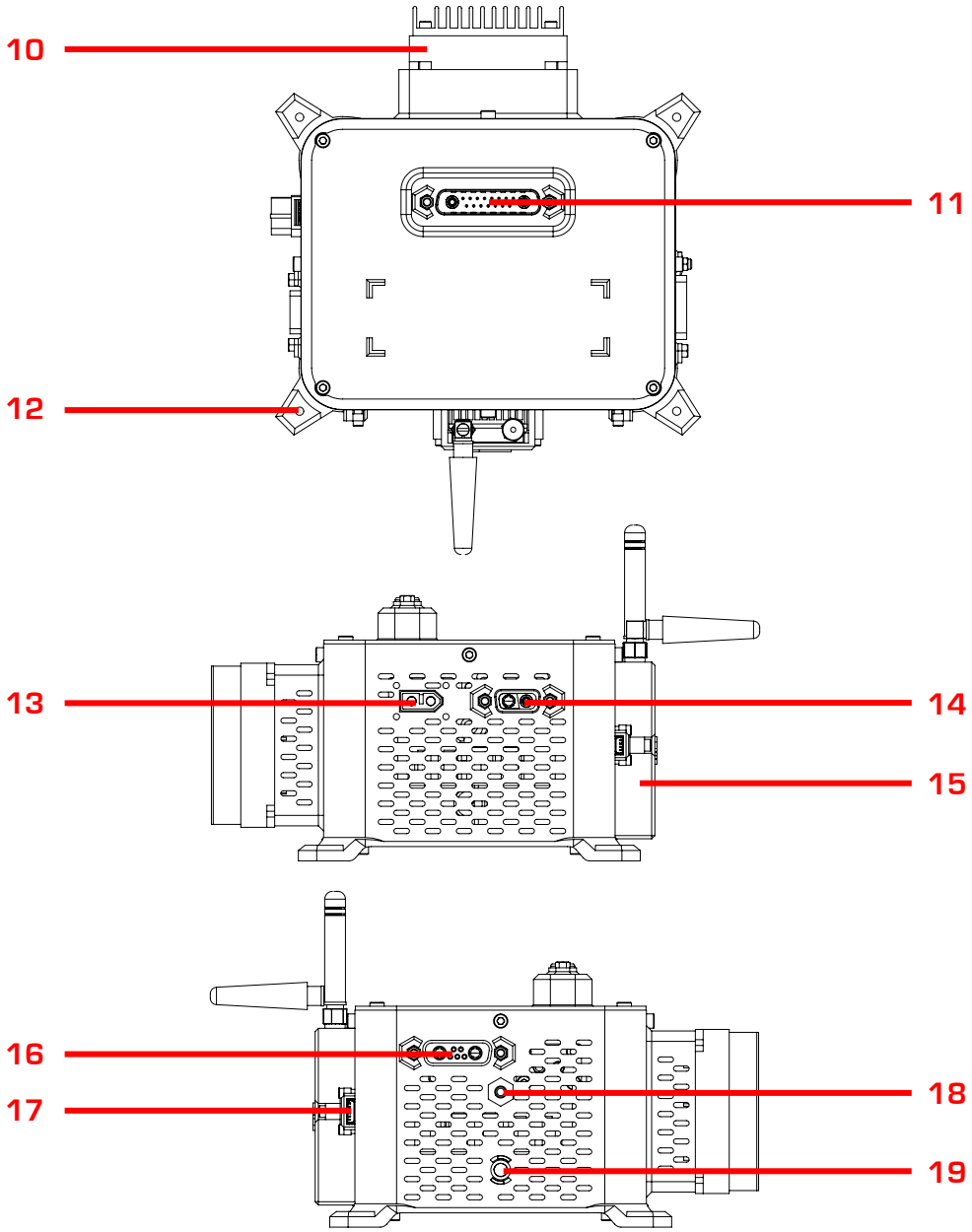


Figure 1.2.1 Top, Left and Right views of Electronic Controller

ITEM	DESCRIPTION
10.	DC-DC converter
11.	Power/Signal header
12.	Mounting hole (x4)
13.	DC-DC power out (XT-60 female)
14.	External power supply receptable
15.	Radio telemetry transmitter
16.	Unregulated stack power out receptable
17.	Programming port
18.	On-Off push button
19.	Status LED

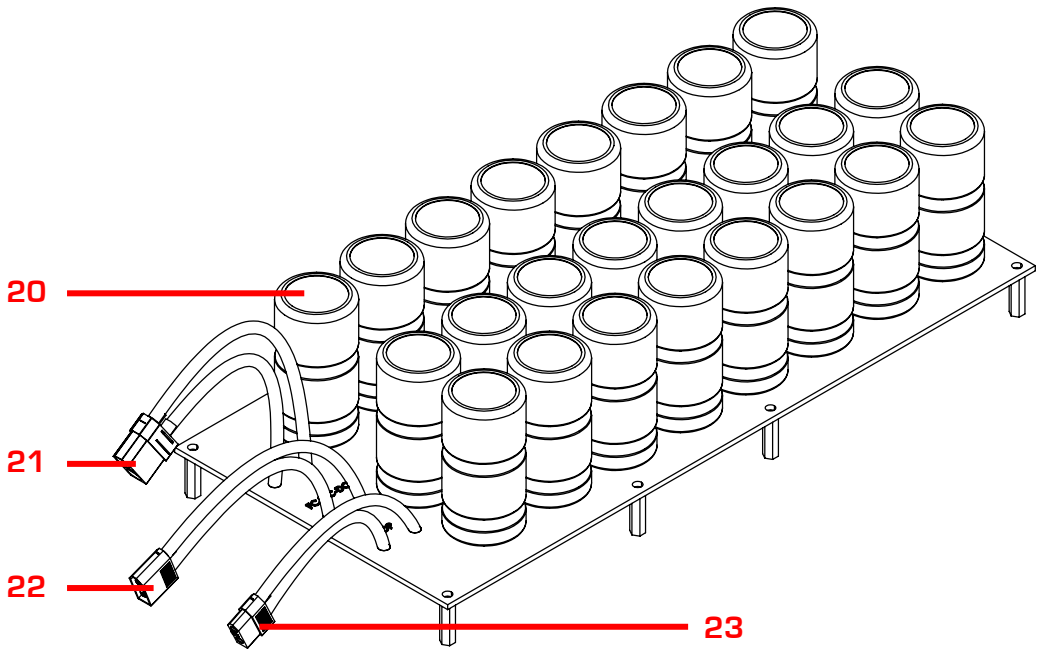


Figure 1.3.1 Supercapacitors pack

ITEM	DESCRIPTION
20.	Supercapacitor (x24)
21.	Load connector (XT-90 female)
22.	DC-DC power out connector (XT-60 male)
23.	External power supply connector (XT-60 female)

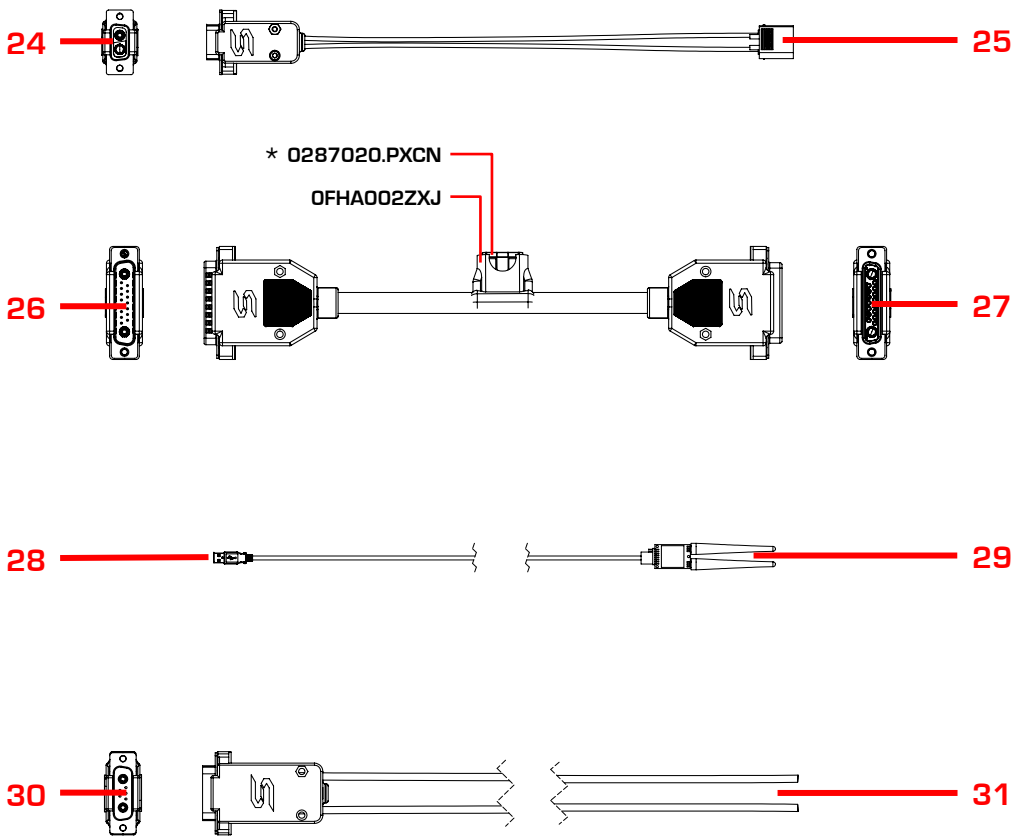
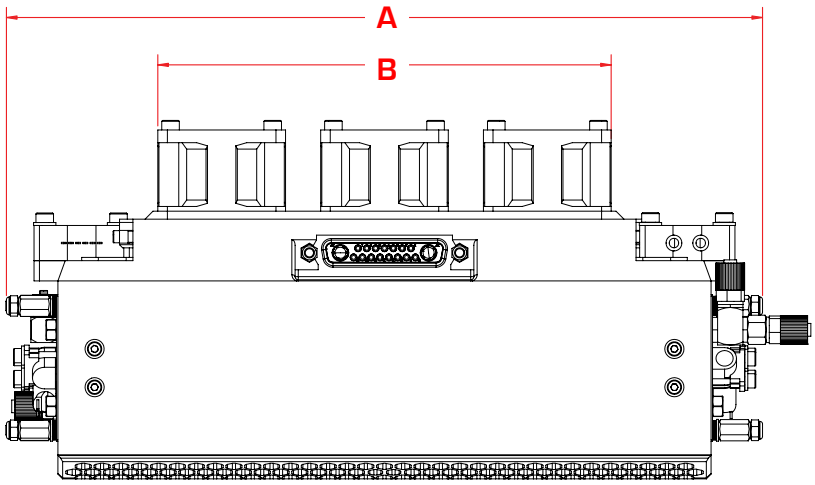


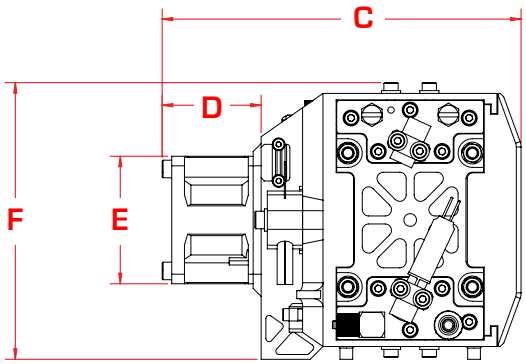
Figure 1.3.2 External power supply cable, power/signal extension cable

*In compliance with Shell Eco Marathon competition rules, the fuel cell power output cable comes with ATOF®-series 20A, 32V fast acting Blade Fuse (Part No. 0287020.PXCN) and fuseholder (Part No. 0FHA0002ZXJ).

ITEM	DESCRIPTION	ITEM	DESCRIPTION
24.	External power supply header	**28.**	USB connector to PC
25.	External power supply connector (XT-60 male)	**29.**	Radio modem receiver
26.	Power/signal extension cable (header)	**30.**	Unregulated stack power out header
27.	Power/signal extension cable (receptacle)	**31.**	Free-end wires to load

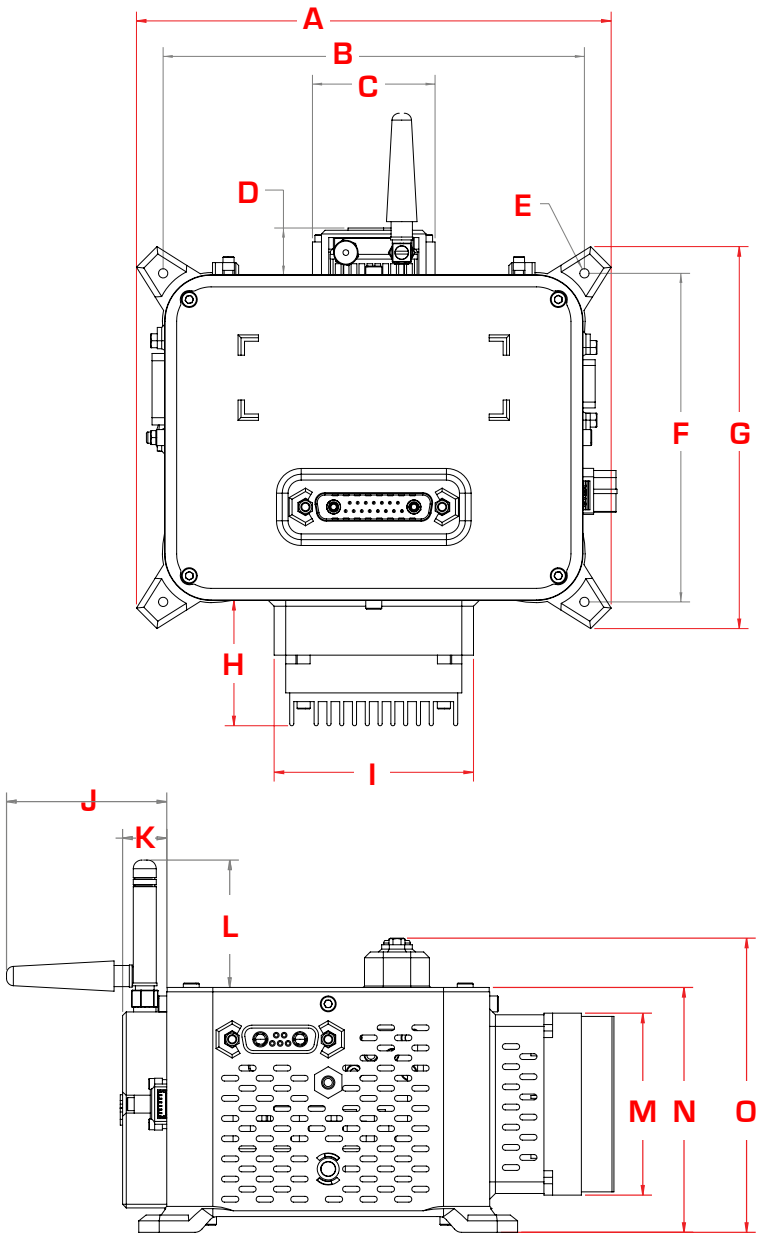
1.4 MECHANICAL DIMENSION – PROTIUM-375





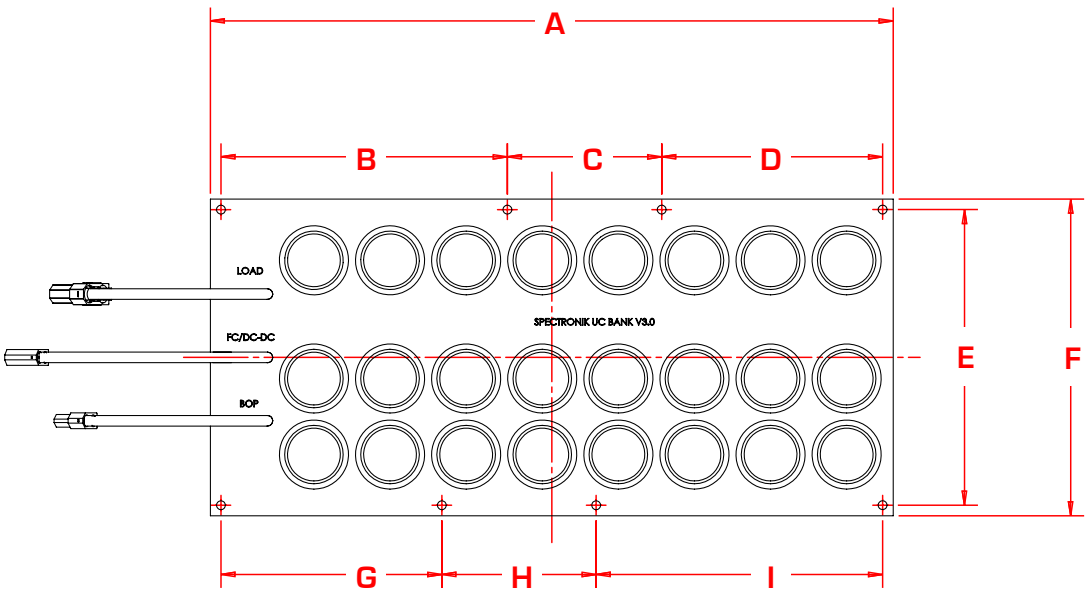
ALL DIMENSIONS IN MM			
A	236.80	**D**	31.00
B	142.00	**E**	40.00
C	112.50	**F**	86.80

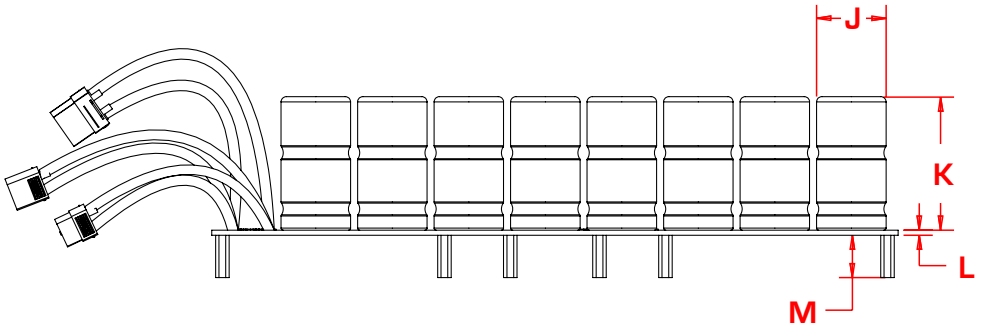
1.5 MECHANICAL DIMENSION – ELECTRONIC CONTROLLER



ALL DIMENSIONS IN MM					
A	163.40	**F**	113.00	**K**	15.30
B	145.00	**G**	131.40	**L**	44.22
C	42.20	**H**	43.10	**M**	63.20
D	16.25	**I**	68.60	**N**	85.00
E	∅ 3.20 (4x)	**J**	55.58	**O**	102.10

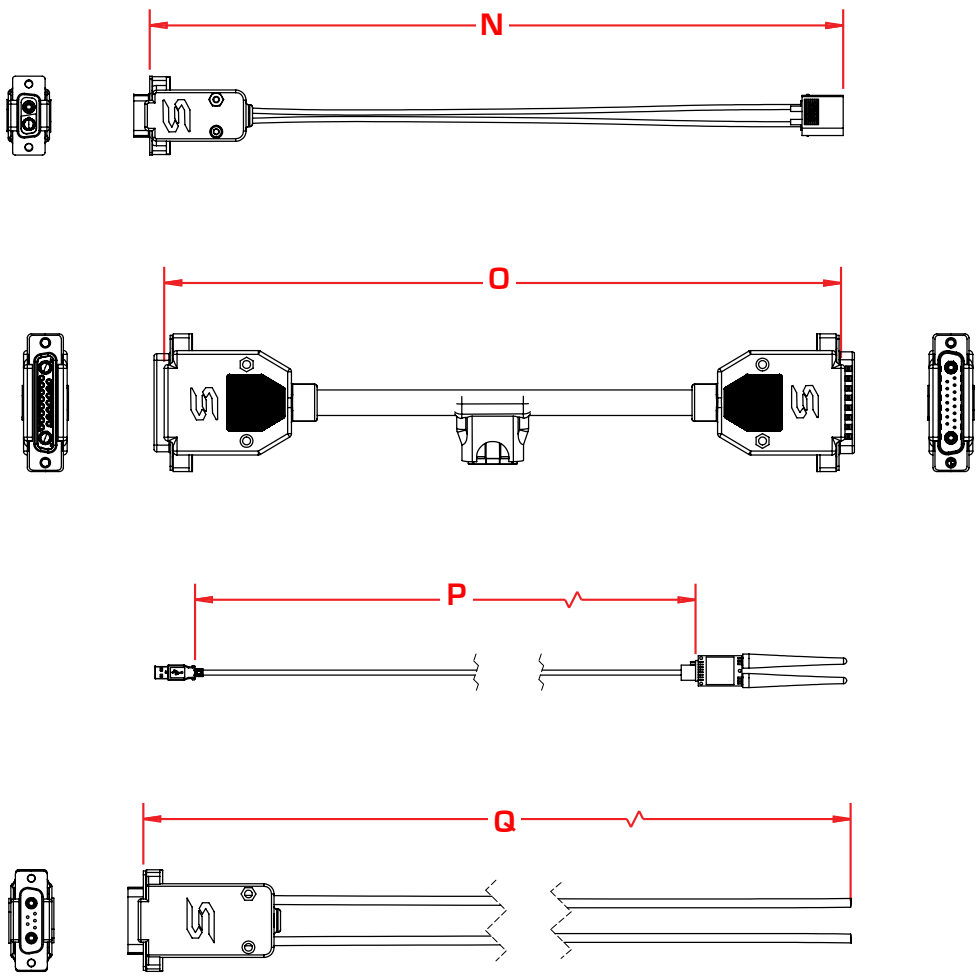
1.6 MECHANICAL DIMENSION – STANDARD ACCESSORIES





ALL DIMENSIONS IN MM					
A	323.00	**F**	150.00	**K**	62.50 ± 1.0
B	135.50	**G**	104.50	**L**	2.40
C	73.00	**H**	73.00	**M**	20.00
D	104.50	**I**	135.50		
E	140.00	**J**	∅ 33.00 ± 1.0		

1.6 MECHANICAL DIMENSION – STANDARD ACCESSORIES



ALL DIMENSIONS IN MM			
N	1000	**P**	1800
O	1000	**Q**	1000

1.7 MOUNTING AND AIR CLEARANCE

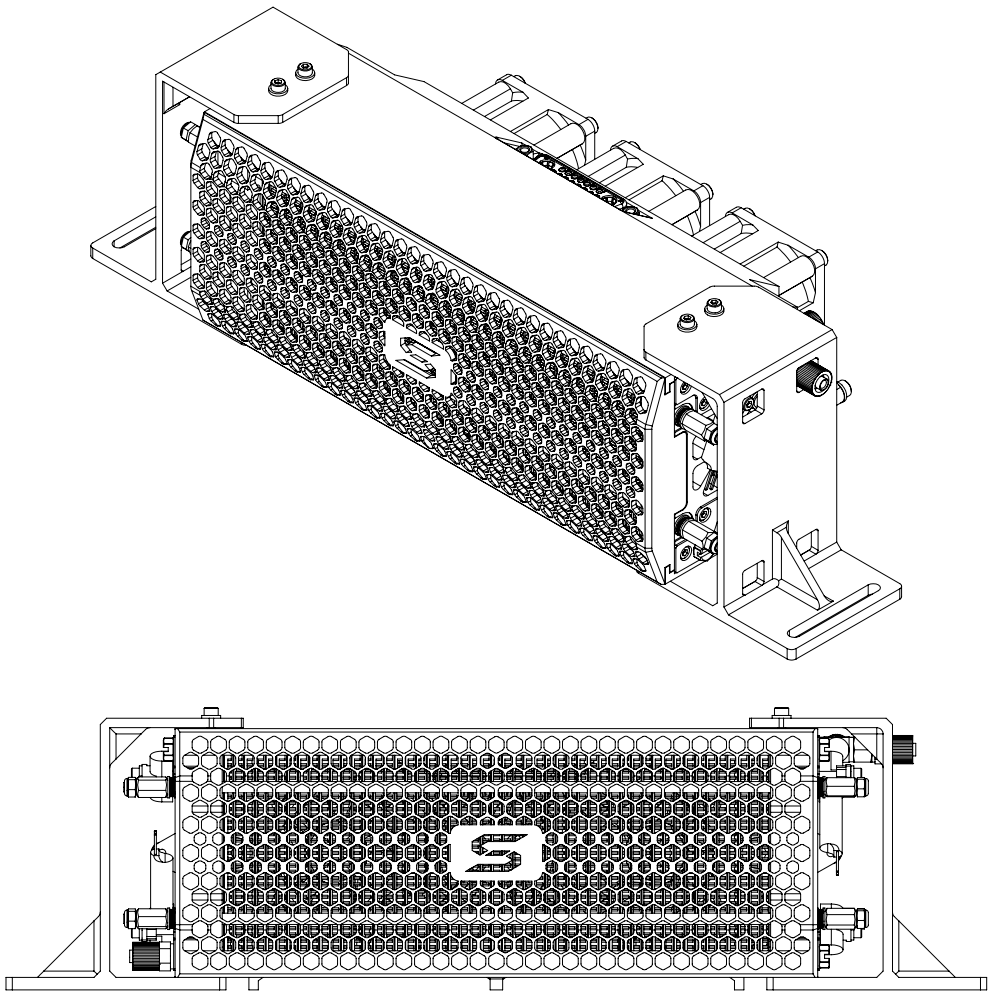


Figure 1.7.1 Recommended orientation of PROTIUM-375

PROTIUM-375 ***cannot*** be mounted in any orientation due to internal routings of the gas streams within the fuel cell stack.

The fuel inlet must always be higher than the fuel outlet. The stack should also be level to ensure water does not get trapped in the gas channels, obstructing the gas flow and causing potential performance drop and cell damage.

Mount PROTIUM-375 in the recommended orientation above, using the mounting brackets provided.

For optimal oxidant and cooling airflows, it is also recommended that there is at least 15cm unobstructed clearance in front of the protective mask and 30cm unobstructed clearance behind the cooling fans' outlet.

1.8 MECHANICAL DIMENSION – MOUNTING AND CLEARANCE

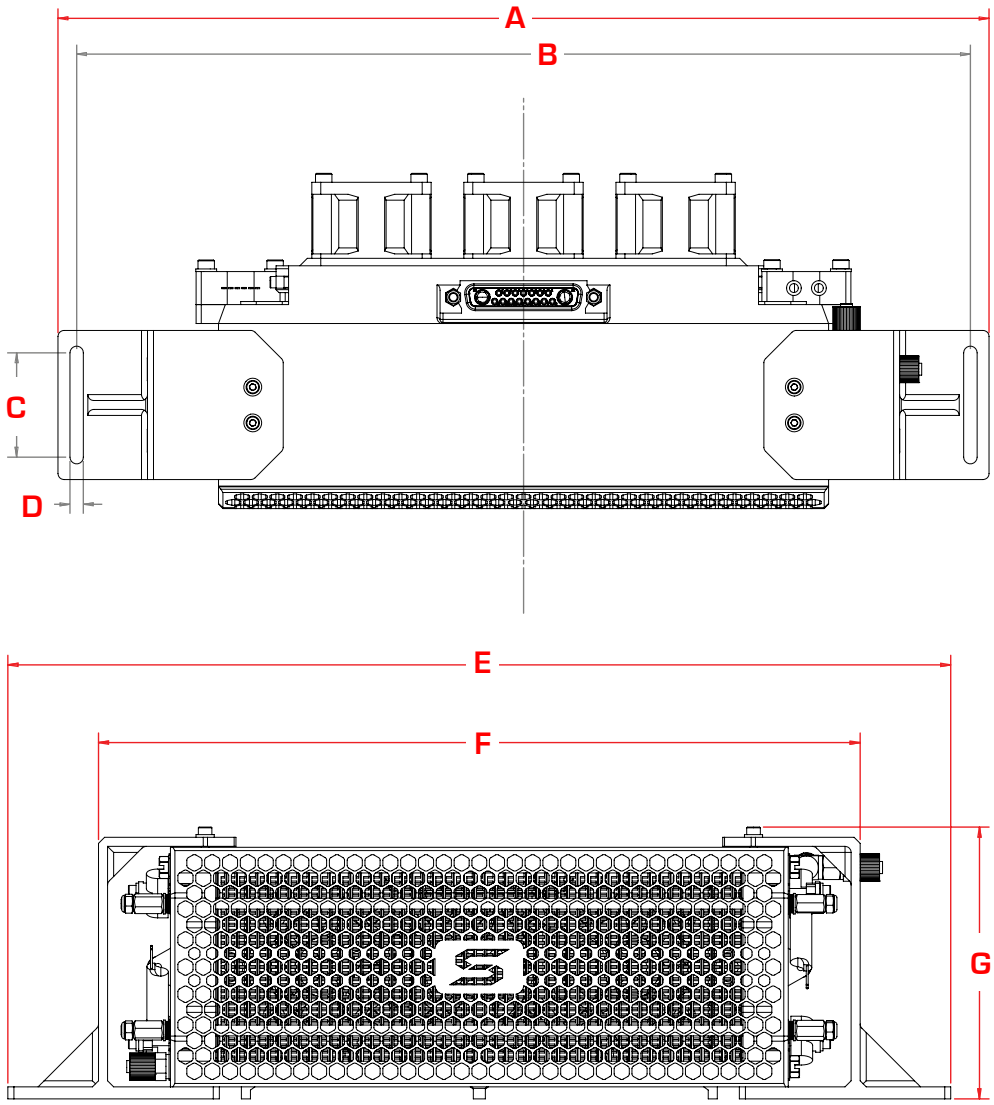


Figure 1.8.1 Dimensions of the mounting holes

ALL DIMENSIONS IN MM			
A	312.20	**E**	312.20
B	299.70	**F**	252.20
C	35.00	**G**	90.10
D	4.50		

2 SPECIFICATIONS

2.1 TECHNICAL DATA SHEET

Fuel Cell	PROTIUM-375
Type	PEM
No. of cells	50
Architecture	Open cathode
Coolant	Air cooled
Rated/gross power	375/450W
Rated/gross current	12.5/15A
Voltage output	30-45VDC
Start-up time	<30s
Operating ambient temperature	[0,35]°C
Operating altitude without power derating	1500m AGL
System weight	1,100g
Max dimension	238 x 113 x 87mm
Cell reaction area	21 sq.cm
Fuse	ATOF®-series 20A, 32V fast acting Blade Fuse Part No. 0287020.PXCN
Fuseholder	Littelfuse Part No. 0FHA0002ZXJ
Fuel Supply	
Hydrogen gas	Dry, 99.999% purity
Delivery pressure	0.4-0.5barg (6-7 psig)
Fuel consumption @ rated power	4.4L/min
Gas tubing	PTFE, 6 x 4
Supply & purge control	Solenoid valves with integrated pressure sensor
Stack leakage checks	Automated via integrated pressure sensors
Electronic Controller	
Processor board	FEATHER V1.2
External power supply requirement	15-90V, 50W max
Weight (including casing)	680g
Output connector	XT-60 female (DC-DC regulated voltage) Harting D sub DA-7W2 (stack unregulated voltage)
Warning & protections	Low voltage, high/low temperature, high/low pressure, low external power supply, stack leakage
Communication	868MHz ultra long range radio modem
Data acquisition (DAQ) software GUI	PC app
Remote control	Fan speed, manual purge, remote on-off

DC-DC Converter	
Type	Non-isolated, half-brick, buck-boost
Input voltage	9-90VDC
Output voltage	0-90VDC user configurable
Output current	0-26A user configurable
Dimension	75 x 61 x 13mm
Weight	210g

NOTE

The output voltage (Vset) and output current (Iset) of the DC-DC converter can be changed according to the user's needs. This provides flexibility for the PROTIUM-375 to be compatible with various DC motor's voltage input range. To protect against current overdraw or to maintain the fuel cell's output at its most optimum power level, Iset can also be configured to limit the maximum allowable current output. Vset and Iset are factory present during time of order for user convenience.

To change Vset, change the resistors on the DC-DC converter's PCB board based on the following formula:

$$Rvset\ (Vset) = \left[\left(\frac{11830 \times Vmax}{Vset + 0.058 \times Vmax}\right) - 10912\right] \quad (\Omega)$$

Where
Vset = desired voltage output (0-90)
Vmax = 90

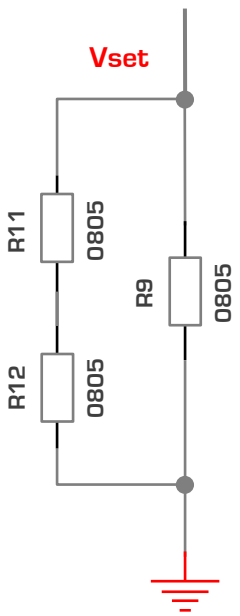


Figure 2.1.1 DC-DC converter's PCB footprint of the resistors for Vset

Caution: Changing Vset may require corresponding change in the number of supercapacitor cells in the supercapacitors pack, as well as firmware update. Contact Spectronik for further advice.

Iset can only be changed via the PC DAQ GUI app. Follow the instructions on Section 3 until step no.1 of section 3.2. After the welcome header appears in the message box of the GUI, use the keyboard function of the GUI and type the following command:

'i' <enter> 'Iset' <enter>, where Iset is your desired current output limit (0-26A, limited to 375W).

For example:

'i' <enter> '5.0' <enter>

If entered correctly, the message "I_set loaded successfully" will appear. Proceed to the next steps as per instructions in section 3.2.

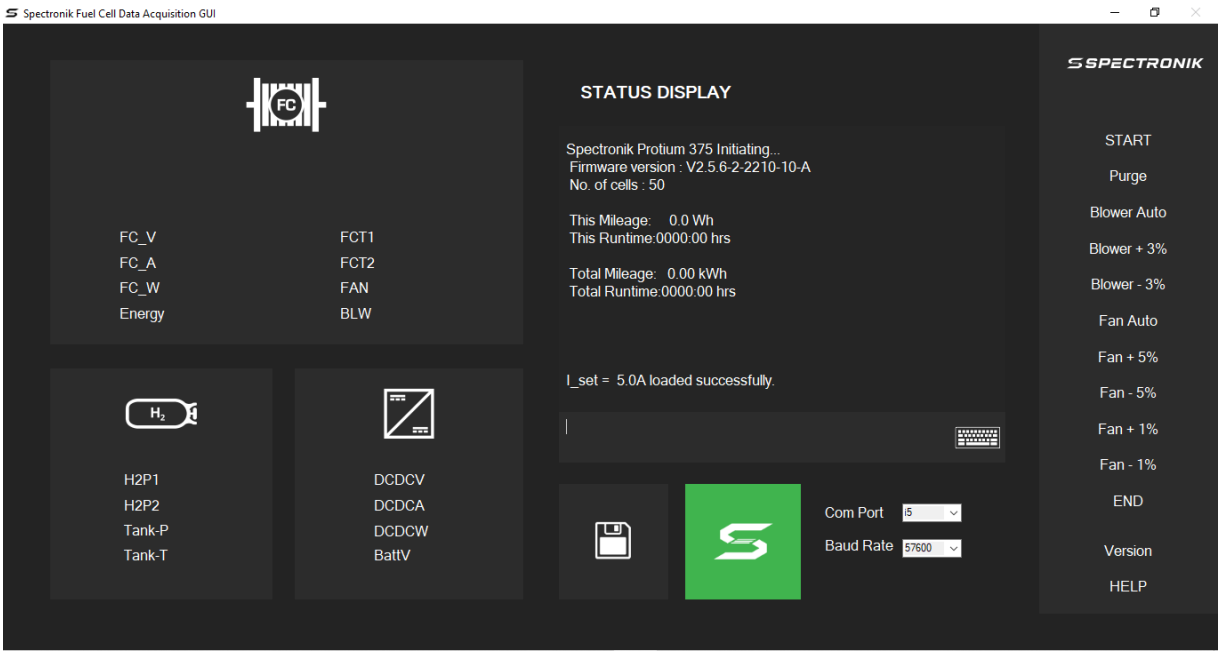


Figure 2.1.2 GUI screenshot showing successful I_set of 5.0A

Supercapacitors	
Model	BCAP0450 P270 S18
Nominal weight per supercapacitor	75g
Quantity	24 pcs in series
PCB mounting	Included
Pack (24 pcs) weight	2.2kg
Pack (24 pcs) dimension	323 x 150 x 83mm

NOTE

The Supercapacitors serve several functions:

1. To provide external power supply to the electronic controller during start-up.
2. To provide external power supply to the electronic controller and fuel cell's balance-of-plant (BOP) when the fuel cell stack carries out Current Pulsing*.
3. To provide additional power output to the motor load during peak acceleration and climbing, in a hybrid parallel configuration to the fuel cell stack output.
4. To receive regenerative braking energy.
5. To be recharged by the fuel cell when excess power is available during cruising.

*The fuel cell stack performs periodic Current Pulsing (once every 15-30s, for a duration of around 100ms) to rejuvenate its cell hydration and maintain optimal performance. During Current pulsing, power output from fuel cell stack to load is momentarily cutoff for safety.

Supercapacitor detailed technical datasheet is attached in Annex A.

The standard pack consists of 24pcs of Supercapacitors in series, and suitable for use up to **60V motor**. For higher motor voltages, contact Spectronik for custom solutions.

2.2 VI CURVE & HYDROGEN EFFICIENCY CURVE

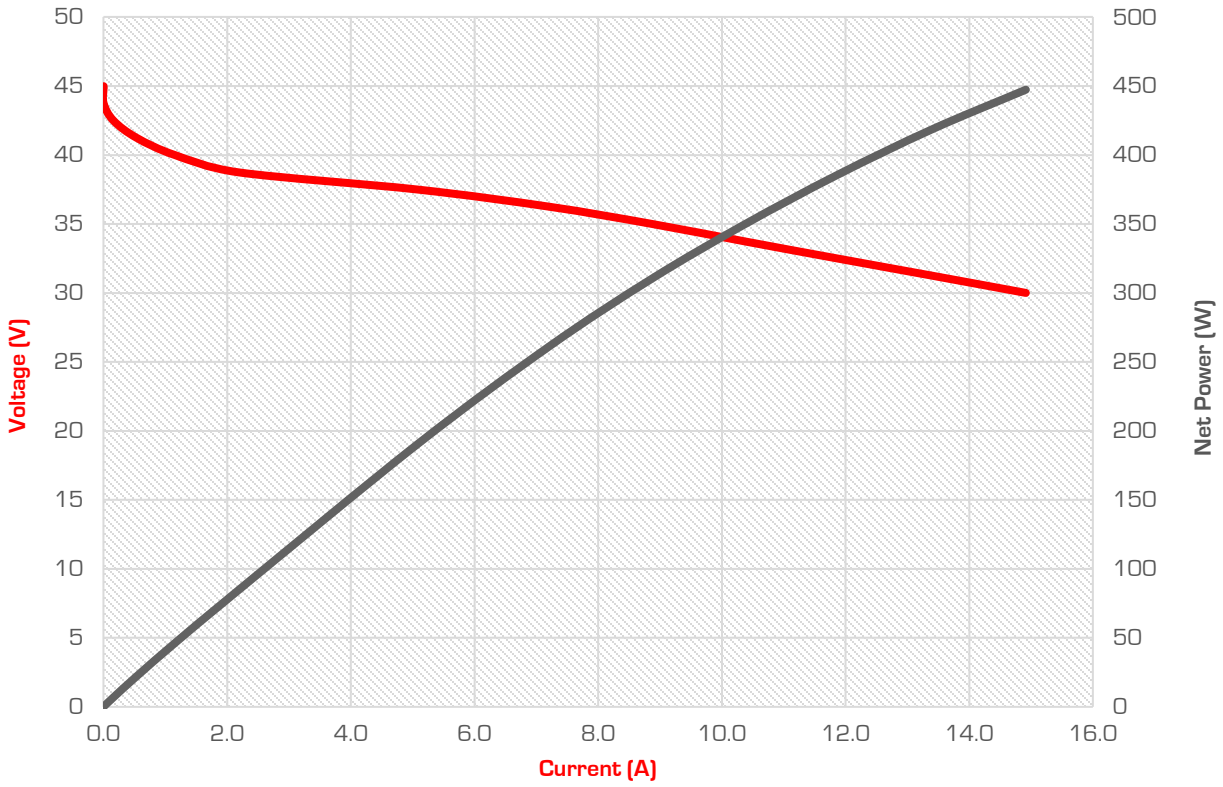


Figure 2.2.1 Nominal polarization curve for a fully conditioned PROTIUM-375 at its Beginning-of-Life (BOL).

TEST CONDITIONS

- Ambient temperature: 24°C
- Relative humidity: 60%
- H_2 supply pressure: 10psig
- Dead-ended operation
- Balance-of-plant (BOP) powered by fuel cell
- T_{cell} at 375W: 54°C

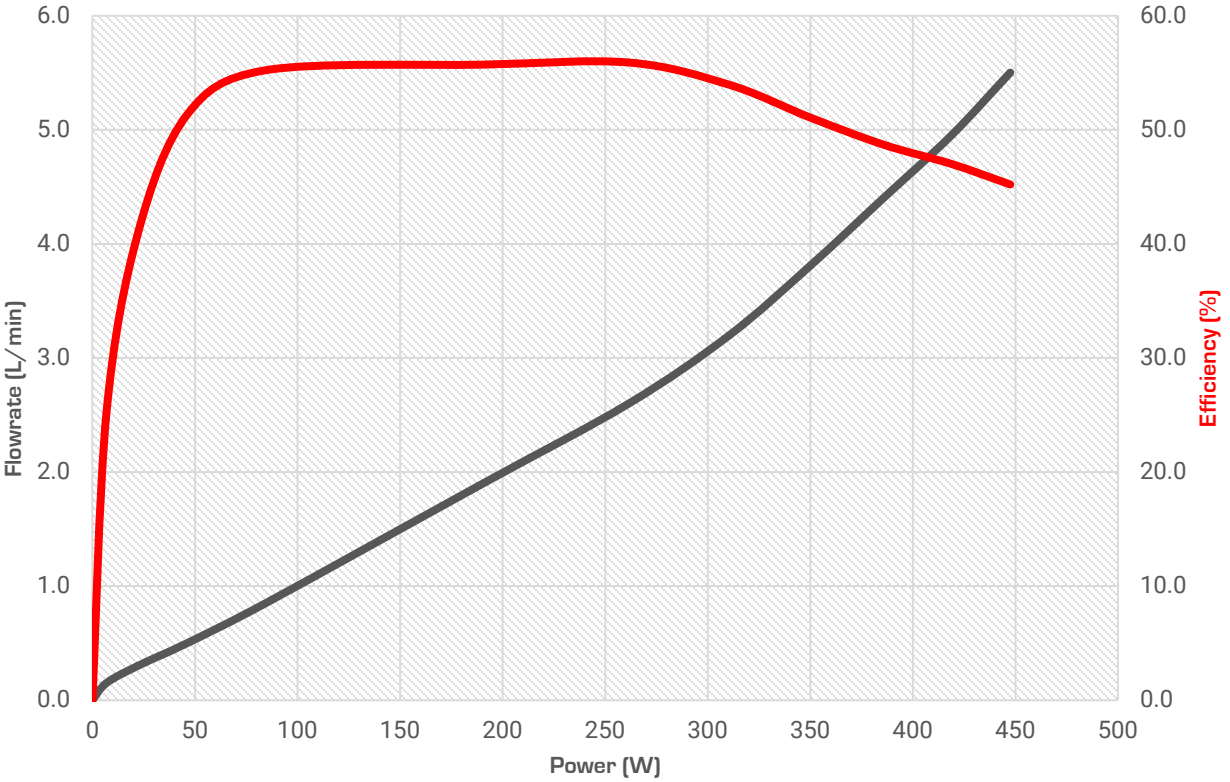
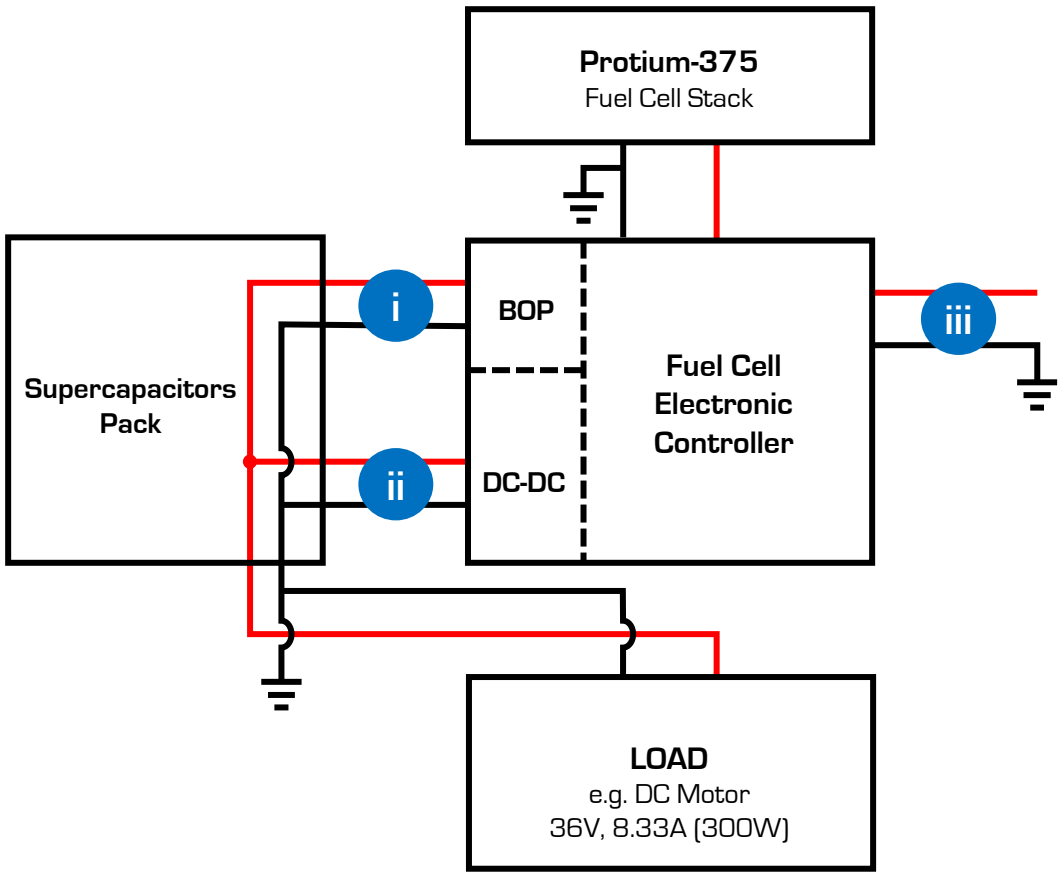


Figure 2.2.2 Hydrogen consumption and efficiency for a fully conditioned PROTIUM-375 at BOL.

NOTES

- Hydrogen consumption is instantaneous reading taken from mass flowmeter at STP.
- PROTIUM-375 is most efficient in the 100-250W range which is the typical nominal cruising power of Eco-Marathon vehicles.

2.3 SYSTEM BLOCK DIAGRAM



i. External power supply (Supercapacitors Pack)
ii. DC-DC regulated output (0-60VDC user configurable Vset, 375W max)
iii. Stack unregulated output (30-45VDC, 375W max)

NOTE

1. An external power supply is required to initially turn on the electronic controller and power the fuel cell's Balance-of-plant (BOP). The Supercapacitors pack will be used as the external power supply.

2. It is recommended that the Iset of the DC-DC converter is set to limit the fuel cell's output to 100-250W range where its efficiency is the highest, although up to 375W can be obtained if desired.

3. Vset should be set to the required voltage of the DC motor load. Note that the Supercapacitors pack will be recharged to Vset during operation if there is excess power available from the fuel cell.

4. For additional safety, power switches are recommended to be installed.

3 OPERATING PROCEDURES

3.1 SETTING UP PROTIUM-375

1. The Supercapacitors pack is not charged when you receive it. Connect a DC power supply to any of the *Load connector (21), DC-DC power out connector (22), or External power supply connector (23).* Limit the current of the DC power supply to 1-2A and set the DC power supply voltage to be the same as your eventual motor load voltage. ***Tip**: this should also be the same voltage as DC-DC converter's Vset.* Turn on the DC power supply to charge the supercapacitors pack. Charging is completed when the voltage reaches Vset and the current output of the DC power supply is almost zero.

2. Mount PROTIUM-375 securely in the recommended orientation.

3. Connect your Hydrogen gas supply to the *H2 gas inlet connector (8)*. Make sure that your Hydrogen gas supply is OFF at this stage.

4. Connect the purge tubing to the *H2 gas outlet connector (6)*. ***Caution:** Channel the purge tubing to the back of the cooling fans and far away from the front mask of the fuel cell stack.*

5. Connect the *power/signal receptacle (1)* of the PROTIUM-375 to the *power/signal header (11)* of the electronic controller, using the *power signal extension cable (26/27).*

6. Connect the *DC-DC power out (13)* of the electronic controller to its corresponding *DC-DC power out connector (22)* on the supercapacitors pack.

7. Connect your DC motor load to the *Load connector (21).* ***Tip**: check that the polarity is correct. It is also advisable to put an ON/OFF switch at your load and ensure that it is turned OFF at this time.*

8. Turn on your PC and connect the radio modem receiver USB cable to a USB port. Download the Spectronik Data Acquisition (DAQ) GUI PC application from the PROTIUM-375 product webpage. Install the app and follow the instructions in its user guide.

***Tip:** You can also use any serial data application like Hyperterminal. Set the parameters (57600 baud rate, 8 data bit, No parity, 1 stop bit).*

***Reminder:** Ensure that all gas tubing and electrical wire connections are firm and secure.*

PROTIUM-375 is now ready to turn on.

3.2 TURNING ON PROTIUM-375

1. Connect the *external power supply connector (23)* of the supercapacitors pack to the *external power supply receptacle (14)* on the electronic controller using the external power supply cable (24/25) provided. Wait for 5s. A welcome header should appear in the GUI. LED will blink at 10%.

2. In the GUI, click the "start" command or type the word "start" and <enter> using the keyboard function. Alternatively, press and hold on *ON/OFF push button* for more than 2s. PROTIUM-375 will enter its "Starting Phase" and the message "Low H2 supply" should appear.

3. Turn on your Hydrogen gas supply. ***Caution:*** *Ensure that the gas delivery pressure is 0.4-0.5barg.*

   Insufficient delivery pressure may cause cell flooding and drop in performance, while excessive pressure may rupture the fuel cell membrane, causing dangerous gas leakage and irreversible cell damage. Ensure that your pressure regulator can provide Hydrogen gas flow rate of more than 5L/min.

4. PROTIUM-375 will do a series of gas purging and internal diagnostic checks. If everything is normal, the fuel cell will enter its "Running Phase" – indicated by the message in the GUI and a solid white LED.

PROTIUM-375 is now ready to power your application.

3.3 POWERING YOUR LOAD WITH PROTIUM-375

1. Turn ON your load and draw power as per normal. Caution: never draw power beyond 375W.

If Iset is implemented, the fuel cell will not deliver more than the Iset current to the load. Excess power required by the load would then be supplied by the supercapacitors pack.

2. During Running Phase, the following live status of the fuel cell can be monitored from the GUI.

Parameters	Description
FCV	FC voltage (V)
FCA	FC current (A)
FCW	FC power (W)
Energy	Energy delivered by the fuel cell during this operation (Wh)
FCT1	FC temperature at location 1 (˚C)
FAN	Cooling fan duty cycle (%)
H2P1	H_2 supply pressure (Barg)
H2P2	H_2 pressure in FC (Barg)
Tank-P*	Gas tank pressure (Barg)
Tank-T*	Gas tank temperature (˚C)
BattV	External power supply voltage (V)

*with purchase of optional Spectronik accessories.

3.4 SHUTTING DOWN PROTIUM-375

1. Turn OFF your load. The fuel cell will continue charging the supercapacitors pack until it reaches Vset voltage. The cooling fans will then turn faster to cool down the fuel cell, before returning to their minimum speed.

2. In the GUI, click "end" command or type "end" and <enter> using the keyboard function. Alternatively, press and hold the *ON/OFF push button* for more than 2s. The message "Shutdown Initiated" will appear in the GUI and PROTIUM-375 will enter its "Shutdown Phase". The system is now OFF. LED will blink at 60% on standby awaiting the next start-up command.

3. If you do not intend to restart the system soon, turn OFF your Hydrogen gas supply and remove the Hydrogen gas tubing from the *H_2 gas inlet connector (8).* Caution: some remaining gas in the tubing will be released into the atmosphere.

4. Turn OFF the external power supply by plugging out the supercapacitors pack from the electronic controller.

PROTIUM-375 is now ready to be kept for storage.

4 SYSTEM MONITORING, PROTECTIONS & MANUAL CONTROL

4.1 MANUALLY CONTROLLING THE PROTIUM-375

The PROTIUM-375 comes with in-built firmware control that is optimized to bring out its best performance over the applicable ambient environment range. In normal use-case scenario, there is no need for user to fine-tune the parameters. For advanced user who wishes to control the fuel cell manually, the following commands can be entered via Hyperterminal or the GUI's keyboard function.

Command	PROTIUM-375 action
start <enter>	Starts the system
end <enter>	Enters normal shutdown phase
ver <enter>	Displays the firmware version
f <enter>	Return to automatic cooling fan control
p <enter>	Open the Hydrogen purge valve for 2s. This is useful to remove excess water if cell flooding is suspected due to decreasing power output.
= (equal)	Increase cooling fan speed by 5% (manual control)
- (hyphen)	Decrease cooling fan speed by 5% (manual control)
0	Increase cooling fan speed by 1% (manual control)
9	Decrease cooling fan speed by 1% (manual control)

Tip: you may also long press the *ON/OFF push button* by >2s to turn ON/OFF the system instead of entering "start" and "end" command via the GUI.

4.2 SYSTEM WARNING & PROTECTIONS

PROTIUM-375 has several in-built protections. The LED will flash and error message will appear in the GUI. Follow the basic troubleshooting guide below. Most errors should be rectified once the suggested corrective action has been done and the system restarted.

If the error persists, contact support@spectronik.com.

4.2 SYSTEM WARNING & PROTECTIONS (Cont.)

Warning messages during "Starting Phase":

Message	Meaning/ Corrective Action
"Gas Tank Not Detected"*	Either the gas tank communication cable is not connected or the tank is empty.
"Gas Tank Pressure Low" *	There is less than 20 Bar remaining in the gas tank.
"Gas Tank Insufficient Pressure" *◉	There is not enough pressure in the gas tank to start.
"Error: Gas Tank at High Temperature" *◉	The Gas Tank internal temperature is above 60°C. Please check for abnormalities.
"Low H2 Supply"	Hydrogen supply pressure is low and the system will wait up to 1min for correction. Please check and correct the delivery pressure.
"Error: Low H2 Supply" ◉	Hydrogen is not correctly supplied within the stipulated time limit. Check and ensure sufficient Hydrogen supply and correct delivery pressure. Restart the system.
"Over Pressure"	Hydrogen supply pressure is too high and the system will wait for 1min. Reduce the delivery pressure.
"Error: Over Pressure" ◉	Hydrogen is not properly supplied within the stipulated time limit. Check and ensure sufficient Hydrogen supply and correct delivery pressure. Restart the system.
"High Temperature"	Stack temperature is too high and the system will wait for 1min.
"Error: High Temperature" ◉	Disconnect everything and wait for system to cool down and restart after 10min. If the problem persists, internal temperature sensor might have been compromised. Contact Spectronik.
"Error: FC Over Cooled" ◉	Stack temperature is too low. Wait for ambient temperature to increase and restart the system.
"FC Sealing Compromised" ◉	Possible stack leakage. Check and ensure all gas tubing and connectors are securely connected.
"Error: Low Voltage" ◉	Stack open circuit voltage is too low. Check and ensure sufficient hydrogen supply and correct delivery pressure. Restart after 1 min.

◉ Emergency Shutdown = "Abnormal Shutdown" would be activated

** with purchase of optional Spectronik accessories (gas tank and pressure regulator)*

4.2 SYSTEM WARNING & PROTECTIONS (Cont.)

Warning messages during "Running Phase":

Message	Meaning/ Corrective Action
"High Temperature" ●	Stack temperature is too high. The fuel cell power output to load will be temporarily disconnected for 5s for system to recover. LED will blink. Reduce your load.
"Error: High Temperature" ◉	Stack temperature is too high. Disconnect everything and wait for system to cool down and restart after 10min. If the problem persists, internal temperature sensor might have been compromised. Contact Spectronik.
"Low Temperature" ●	Stack temperature is low. LED will blink.
"Error: FC Over Cooled" ◉	Stack temperature is too low for operation.
"Low Voltage" ●	Stack Voltage at minimum threshold of 0.6V/cell.
"Error: Low Voltage" ◉	Stack Voltage below safety threshold limit.
"Low H2 Supply" ●	Hydrogen supply pressure is low and the fuel cell power output to load will be temporarily disconnected. LED will blink. Check and ensure sufficient Hydrogen supply and correct delivery pressure.
"Error: Low H2 Supply" ◉	Hydrogen supply pressure is too low. Check and ensure sufficient Hydrogen supply and correct delivery pressure. Restart the system.
"High H2 Supply Pressure" ●	Hydrogen supply pressure is too high and the supply valve will be temporarily shut off. LED will blink at 80%. Reduce the delivery pressure.
"Error: High H2 Supply Pressure" ◉	Hydrogen supply pressure is too high. Check and ensure sufficient Hydrogen supply and correct delivery pressure. Restart the system.
"Low Battery" ●	The External Power Supply is at below 15V.
"Gas Tank Running Low" *●	The pressure in the gas tank is below 20 Bar.
"Gas Tank Depleting" *●	The pressure in the gas tank is below 10 Bar.
"Error: Gas Tank at High Temperature" *◉	The Gas Tank internal temperature is above 60°C. Please check for abnormalities.

◉ *Emergency Shutdown = "Abnormal Shutdown" would be activated*

● *LED flashing at 80% to alert warning in the running*

** with purchase of optional Spectronik accessories (gas tank and pressure regulator)*

4.2 SYSTEM WARNING & PROTECTIONS (Cont.)

Other messages:

Message	Meaning
Fan PWM auto	Cooling fans control is in auto mode
Mileage	Cumulative Watt-Hour of the system
Shutdown initiated	Entering “Normal Shutdown Phase”
Abnormal Shutdown initiated	Entering “Abnormal Shutdown Phase” due to an error
System off	System is turned off and ready to restart at the next command

LED status:

Phase	Blink % (at 1Hz)	Meaning
Power ON	10%	5s after start-up power is provided into the fuel cell controller, LED will blink at 10%, indicating that the system is ready to receive its “start” command
Starting Phase	40%	Executing “Starting Phase” procedures
Running Phase	100%	System in normal “Running Phase”
Running Phase	80%	System warning during “Running Phase”
After shutdown	60%	System off due to normal shutdown and on standby for the next “start” command
After shutdown	0%	System off due to abnormal shutdown

5 MAINTENANCE AND STORAGE

5.1 MAINTENANCE FOR PROTIUM-375

When not in use, Spectronik recommends that PROTIUM-375 is reconditioned at least once a month.

1. Set up PROTIUM-375 as per instructions in Section 3, taking note of the following differences:

a. Use a DC power supply instead of the Supercapacitors pack. Set the DC power supply to 30V 2A.

b. Do not use the *DC-DC power out (13)* socket.

c. Connect the *Unregulated stack power out header (30)* to its respective *unregulated stack power out receptacle (16)* on the electronic controller. Next, connect the *free-end wires (31)* to a DC electronic load. Caution: ensure that the polarity is correct.

2. After the system enters "Running Phase", set constant voltage (CV) load of 30V and run the system for 1h. The fuel cell should recover to its maximum rated power output.

PROTIUM-375 is now ready for usual operation or can be stored again for future use.

5.2 STORAGE

Keep PROTIUM-375 in an open, cool (standard room temperature of 25°C) and dry place.