



# **Operating Manual**



Fueling the Hydrogen Economy Power & Energy, Inc. | 106 Railroad Drive Ivyland, PA 18974-1449 USA



# For use with $\mathsf{HEMS}^{^{\mathrm{TM}}}$

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# **General Overview**

The Power+Energy HEMS<sup>™</sup> Hydrogen Purity Analyzer is a full spectrum instrument with limits of detection better than that specified in ISO14687 and SAE-J2719 standards. HEMS is an acronym for *Hydrogen Elimination Measurement System*, and it encompasses proprietary sample concentration an injection technologies, P+E's novel palladium membrane technologies with commercial, off-the-shelf gas chromatography columns and P&E's modified version of standard thermal conductivity detectors. The system eliminates nearly all of the hydrogen while concentrating the gas impurities. The HEMS is portable and can be transported with the power on. The analyzer is calibrated using traceable calibrated gas after production. Cycle time is relatively short for analytical measurements and can be used as an on-line purity monitor for hydrogen fueling FC vehicle.

The HEMS instrument is an analyzer of pure hydrogen streams for the detection and quantification of impurities in the SAE/ISO specs shown in *Table 1*. The instrument is designed to take samples directly from a hydrogen feed supply through a dedicated sample port. The system is simple to operate through a touch panel display and can be configured to automatically sample multiple times without an operator present. If measurements exceed the ISO/SAE specifications reading are held until cleared by the user. The compact package and automatic operation make it easy to use for quick sample verification. The HEMS analyzer is the result of 10+ years of research and development.

Casas Massurad	SAE-J2719	Targeted	
Gases Measured	ISO-14687	Lower Detection Level	Upper Detection Level
	(ppm)	(ppm)	(ppm)
Nitrogen (N <sub>2</sub> )	100	25	150
Helium (He)	300	75	450
Argon (Ar)	100	25	150
Carbon Monoxide (CO)	0.2	0.05	0.3
Methane (CH <sub>4</sub> )	2	0.5	10
Water (H <sub>2</sub> O)	5	1.6	7.5
Oxygen (O <sub>2</sub> )	5	1.3	7.5
Carbon Dioxide (CO <sub>2</sub> )	2	0.5	3
Ammonia	0.1	0.025	0.15
Hydrogen Sulfide (H <sub>2</sub> S)*	0.004	0.001	0.006
Carbonyl Sulfide (COS)*	Inclusive	Inclusive	Inclusive
Carbon Disulfide (CS <sub>2</sub> )*	Inclusive	Inclusive	Inclusive

The HEMS instrument quantifies impurities in the ISO14687 and SAE-J2719 standards.

\*H2S+COS+CS2 < .004 ppm

#### Table 1

**The HEMS (Hydrogen Elimination Measurement System)** analyzer uses P+E's patented palladium diffusion technology combined with advanced thermal management, sample concentration, high-speed thermal injection, and low-noise high-resolution electronics to achieve sub-parts-per-billion resolution, using simple thermal conductivity detection.

**Compared to other analyzers**, HEMS offers detection of the broadest range of impurities in a compact enclosure with automated operation at an affordable cost.

# **HEMS Benefits / Advantages**

- 1) Large dynamic range and high resolution, resolving ppm, ppb and ppt levels of contamination
- 2) GC columns separate different molecular species with the same mass a. Uses a GC column to separate  $N_2$  & CO
- 3) Measures a wider range of compounds vs. optical methods and measures individually both N2 and CO vs APIMS.
- 4) More compact, lower cost, low maintenance, lighter than competing analyzers.
- 5) Rugged and simple to operate
- 6) Capable of moving while powered on (except filament power must be off)
- 7) On-site Analysis of Hydrogen Quality
- 8) Measurement time typically less than 20 minutes
- 9) Concentrates Impurities from 1 to 10,000+ using proprietary technology
- 10) Sensitivity < 1 ppb
- 11) Typical H2 flow rate (including carrier gas) is less than 100 sccm,
  - a) Average flow rate less than 100 sccm
  - b) Sample size less than 500 scc
- 12) Generates UPH (Ultra Pure Hydrogen) carrier gas from the sample stream, purity < 1 ppb
- 13) Measurements are made using a rugged Thermal Conductivity Detection
- 14) All sample lines are 316L protected with Silconert coatings
- 15) Analysis can be done for other contaminates with additional calibration

# **Operating Principle**

**HEMS** collects impurities from flowing a sample of the gas under test thru a propriety micro-volume held at a low temperature. The collection time ranges from a second to 10 minutes. The impurities concentrated at low temperatures. They are then thermally injected into the high-purity hydrogen gas stream and separated by GC columns based on their characteristics.

**HEMS** is calibrated at P+E using ultra-pure hydrogen to dilute the Calibrated and Certified reference gases to the appropriate concentration level.

The Micro-Channel Palladium Membranes generate the ultra-pure hydrogen gas from the sample gas, avoiding the complication of having to supply ultra-pure gas from a bottle.





Figure 1: Typical screenshot showing the analysis of a hydrogen sample



# Installation

Upon receiving the instrument, inspect the unit for damage which may have occurred during shipping. The unit is shipped back filled ~ 5 psig (0.034 MPa) of UHP Argon in order to ensure HEMS it is in a known state. The instrument should be mounted on a flat, horizontal surface capable of supporting the weight of the instrument. It is important to leave enough clearance around the air vents not to obstruct air flow. The air vents are located on both the left and right side of the instrument. During operation, the instrument must not be moved to prevent component damage.



Figure 2: HEMS Front with labeled features



Figure 3: HEMS Back with labeled features

# **Power Connection**

Using a power cord, connect the instrument to a power outlet shown in Figure 3 Inspect the power cord to make sure it is free of defects.

The instrument accepts input voltage in the range 90 - 260 VAC single phase and frequency in the range 47-63 Hz through a Power receptacle located on the black rear panel on the instrument. The power entry module includes the main power switch and Circuit Breaker.

# **Gas Connections**

Hydrogen gas to be analyzed is supplied the instrument to through 1/8" Bulkhead а connector on the top LEFT of the instrument. All input parts have been Silconert coated to maintain integrity of the sample inlet gas. All gas is vented through a 1/4 consistent with page 9" Bulkhead connector labeled "vent" on the RIGHT side top of the HEMS. Both sample and vent use high purity compression fittings.

**Sample Inlet** (*labeled "Sample H2 Inlet" in Figures 3 and 4*). This port should be connected to the hydrogen sample to analyze. Respect the following ratings:

- Maximum pressure 142 PSIG (0.98 MPa) Or the maximum pressure for hydrogen in your area, whichever is less. The pressure we use is 0.98Mpa or less.
- Minimum H2 pressure is 0.62Mpa (90psig).
- Minimum hydrogen purity (99.97%)
- Connect sample line to the 1/8" Bulkhead fitting on the top left of the instrument. This is the Sample H2 inlet port.

**Vent** (*labeled "Processed Gas Exit" in Figures 3 and 4*). Connect the port labeled vent to a safe location with sufficient ventilation using a minimum size ¼" tubing with minimum inner diameter of 0.18".

**NOTE:** When HEMS is not in use be sure to replace the cap over inlet and vent port connects and tighten lightly. It is recommended to flush the sampling line connected to the sample inlet and purge for approximately 10 minutes with the Sample pressure within spec, before making a measurement for the first time.



CAUTION – MAKE SURE THE VENT IS CONNECTED TO A VENT LINE AND IS UNOBSTRUCTED.



NOTE – Follow industry standards for the connection of the vent. Make sure that the concentration of the hydrogen vented is not within the flammability limit.



WARNING - DO NOT EXCEED THE PRESSURE RATINGS SPECIFIED.

# **Detailed Operation**

# System Startup

#### System connections

Connect the Power Cord into the receptacle in black electrical box at the back of the unit. Power up the instrument by turning on the main switch above the power receptacle as shown in Figure 3. Make sure the pressure at the gas ports is in the range specified in the subsection gas connections of the installation section of this manual. Connect the sample to the 1/8'' Bulkhead Compression fitting on the top left side of the instrument.

#### ✤ System initialization

When the system is turned ON. The system sets all the default settings as the initialization of system take place. The touch screen will indicate the HOME screen as shown in below figure, after completing the initialization. The system goes through heating process and it will take about 45-60 minutes for the system to stabilize.

Note: System to Stabilize depends on many parameter. The initial parameter is the Pd cell temperature and  $2^{nd}$  the oven temperature.



Figure 4 : Details of the controls in Home Page



- 1. HOME
- 2. START TEST / ABORT TEST
- 3. CONFIGURATION
- 4. EXPORT
- 5. REPORT
- 6. SHUTDOWN
- 7. VERSION NO
- 8. HARDWARE STATUS
- 9. CARRIER A PRESSURE INDICATOR
- 10. CARRIER B PRESSURE INDICATOR
- 11. SAMPLE PRESSURE INDICATOR
- 12. STATUS BAR
- 13. PROCESS STATUS
- 14. SYSTEM PRESSURE INDICATOR
- 15. ABOUT
- 16. Pd CELL STAUS INDICATOR
- **17. BLOCK READY STATUS INDICATOR**
- **18. HEATER STATUS INDICATOR**
- 19. SYSTEM TIME

# Home 望

The Home screen displays the sample pressure, carrier pressure, Pd cell status, Block (Oven) status, heaters status. As shown in below figure are the status of the heaters & Pd cell. The block is heating to stabilize the system for starting the test. When the heaters are ON, it indicates . And when the Block (Oven) and Filaments are at temperature is ready it indicates . Once the entire system is ready, the **TEST** button is enabled for the user to click and start the test. The system checks for the

System Pressure 95.0 PSI

pressure and if the pressure is in the range, it displays it in the screen as shown

. If the pressure range is low/high, the indicator starts blinking and displays as shown







Figure 5 : Home Page

# Test 🧟

The user can start the test by clicking the **Test** button<sup>1</sup>. For this Button to light the temperatures need to be stabilized and all pressures in the operating range.

#### Step 1: Test Initialization

The Test Initialization starts when the Test button is pressed.



Figure 6 : Test Initialization

# Step 2: Connect the sample gas check

Checks whether sample gas is connected and turned ON. Press OK Substitution if already connected to cylinder.

Note: If sample gas is not connected, connect the sample to the 1/8" Bulkhead Compression fitting on the top left side of the instrument. This bulkhead fitting has a 1/8" diameter Stainless Steel bar after testing was completed. The "Sample Vent" is a 3/8" Bulkhead Compression fitting. This bulkhead



fitting has a 3/8" diameter Stainless Steel bar in the vent line for shipping and storage. The HEMS has been purge and backfilled with high purity Argon.



Figure 7 : Connect the sample gas check display window

#### Step 3: System Check

The system checks if the temperatures are stabilized at the operating temperatures. If the temperature is not stabilized, the following message will appear: **"Please wait while the HEMS comes to the operating temperatures"**.

Press **OK** Substitution to go back to Home screen.



Figure 8 : Temperature not Stabilized Window

When the system stabilizes it goes to step 4

# Step 4: Pressure Check

The system checks for sample pressure .The sample pressure should be above **65 psig** and below **145 psig**. If the pressure is below or above pressure range its displays a **Low/High Pressure** window as shown in figure below.



Figure 9 : Pressure Low/High display window

If the system pressure is within the range, wait 5 seconds and press OK button 2 and it goes to step 5

# Step 5: Start Measurement

Once the system is stabilized and pressure at desired range, a popup with Ready to begin Measurement window as shown in the below figure. Press OK button to start the test and start storing the data. Press Cancel button to cancel the test and go back to home screen.



Figure 10 : Start Measurement window

Press on Repeat? Button vortigure the no of test to be done as shown in Figure 12





Figure 11 : Configure number of test to be done

Click on up arrow and down arrow to increase and decrease the no. Press OK button to save the configure.

#### Step 6: Test Progress

The test progress is displayed in the screen and it will take approx. 20 min to complete a test. Once the test is completed .It will display the report (Step 7)



Figure 12 : Test in progress window

#### Step 7: Report

The report is generated and displayed after the test is completed. It checks and displays whether the gas is within the SAE-J2719 ISO-14687 spec. If the gases are outside the SAE-J2719 ISO-14687 spec, it displays in red color background display as shown > 6.0. If the gases are below lower limit of detection, it displays in green color background display as shown < 0.5. The gases which are

# CO, ppb

within the SAE-J2719 ISO-14687 spec are displayed with blue background as shown 100.0. The details report are stored in the system and can be transferred to USB stick. Refer <u>DATA EXPORT</u> section to transfer the data files to USB stick

HEMS			02/15/20	18 10:09 AM
	<u>REPO</u>	RT File Name	e : 20180215-10_00_03 Date : 2/15/2018	
H <sub>2</sub> S, ppb	CO, ppb	H <sub>2</sub> O, ppm	N₂, ppm	
>6.0	100.0	<1.6	30.0	
COS, ppb < <b>1.0</b>	NH₃, ppb <25.0	O <sub>2</sub> , ppm < <b>1.3</b>	He, ppm < <b>75.0</b>	<ul><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li><li></li></ul>
CS <sub>2</sub> , ppb	CH₄, ppm	CO <sub>2</sub> , ppm	Ar, ppm	
<1.0	>10.0	<0.5	<25.0	
NOTE : C	Detailed HEMS Repo	ort can be transfere	d to pen drive	
2/15/2018 10:08:57 AM	HEMS Initialized			VER. 1.0

Figure 13 : Report Page





# Configuration 🚳



Figure 15 : Password enter window

#### The configuration has two mode

✤ Maintenance mode

The maintenance mode has the privilege to view all the readings and control the temperature of the heater. It has a password which only P+E or Authorized Distributors uses for maintenance purpose.



Figure 16 : Maintenance mode configuration window



#### Operator mode

The operator are restricted with limited display. It has a password which is **4444**.

Note : Cleaning of the column is recommended to do with experts advice.



Figure 17 : Operate mode configuration window

If the password entered is wrong, it displays Access Denied window as shown in below figure. Press **OK** to go back to Home screen.



Figure 18 : Access Denied window

# System Shutdown 😡

To turn off the instrument press the **Shutdown** Button <sup>120</sup> on the Home Screen .A shutdown screen appears as shown below.



Figure 19 : System shutdown window

# Power Down. 🕕

Once the **POWER DOWN** button is pressed. The system goes to a shutdown process and the software will automatically bring the instrument to a safe state. Once the HMI is shut down, it is safe to shut off the main power switch on the back of the instrument shown in Figure 3.



<u>Warning</u>: Premature shutdown of the main power can damage the internal palladium cell.

# Restart. ᄋ

Once the **RESTART** button is pressed. The system goes through the Shutdown process and restarts the HMI.

# Cancel. 🗙

Press the **CANCEL** button to go back to the previous screen.



# Data Export 🥝

The data & report of the test done can be transferred to the USB stick and then viewed/analyzed on the PC. Follow the steps mentioned below to transfer the data.

#### Step 1: Insert the USB Stick.

Insert a USB stick onto the front of the HEMS system. The EXPORT button will be enabled. Press on the **EXPORT** button *(*) on the Home Screen. An Export screen appears as shown below.



Figure 20 : Data export window

#### Step 2: Data available for transfer.

Press the File Explore button 🧭 . A file explore window appears with all the test data as shown below.

HEMS	
Select the data files to export	-
- 20170513-13_51_38	
- 20170516-15_17_11	
- 20170517-09_26_08	
- 20170517-10_36_36	
- 20170517-10_54_50	
- 20170517-11_13_02	
- 20170517-12_17_03	
- 20170517-12_35_17	
- 20170517-12_53_37	
- 20170517-13_11_52	
SELECT ALL XUNSELECT ALL	

Figure 21 : Data explore window

Note: If there was no test done previously, the data folder will be empty and **NO DATA AVAILABLE** window will appear as shown below.



Figure 22 : No Data available window

# Step 3: Data selection for transfer.

You can select the single file to export from the file explorer or if you want to select all the files press **SELECT ALL** button and it will select all the file which are there. See the figure below.

HEMS	
Select the data files to export	
- 20170513-13_51_38	
- 20170516-15_17_11	
- 20170517-09_26_08	
- 20170517-10_36_36	
- 20170517-10_54_50	
- 20170517-11_13_02	
- 20170517-12_17_03	
<b>-</b> 20170517-12_35_17	
- 20170517-12_53_37	
<b>-</b> 20170517-13_11_52	
SELECT ALL XUNSELECT ALL	

Figure 23 : Data ALL selected to export

Click **OK** button **(2)**, once the data are selected.



#### Step 4: Data transfer.

To transfer the data to USB stick Press the EXPORT 2 button in the Export Screen. The data will be transferred to the USB Stick.



Figure 24 : Data transferring in progress

Note: Do not remove the USB Stick while it is transferring the data.

# Step 5: Close the Export Screen.

Press the Cancel 🕸 button, once the Data transfer is complete and it will exit from the Export screen.



# About

It displays the contact detail of the HEMS manufacturer.



Figure 25 : About Page



# Software Update for HEMS Unit

P&E will provide the updated software.

Step 1: Loading the New Software to USB Stick & Insert onto system.

Copy the new software provided by P&E to a USB stick and insert the USB stick to the front of the HEMS system.

*Note: Copy the entire folder to the USB stick. Do not create a subfolder in USB stick and copy the software into it.* 

#### Step 2: Restart the HEMS system

Press the **Shutdown Button** 😥 on the Home Screen .A shutdown screen appears as shown below.



Figure 26 : System shutdown window

Press the **RESTART** button and the system will go to a restart. Note: Do not remove the USB stick from the system until the update is done. Step 2: Software update

# Step 3: Software update

Once the system restarts, the new HEMS software update Available dialog displays.



Figure 27 : Software Update Available Dialog





Once the User clicks OK button, the software is updated to the sytsem.

Figure 28 : Software updating window

# **Definition of Terms**

# Symbols Used In this Manual





NOTE – The Note sign denotes important information. It calls attention to a critical procedure, practice, or condition.



WARNING – Denotes a hazardous condition or procedure, which, if not properly performed, will damage the equipment, and could cause injury to personnel. <u>Always proceed with care</u>.



# Troubleshooting

Troubleshooting Guide			
Problem	Possible Cause	Correction	
Instrument does not power up	Instrument is not plugged in	Check plug, main power switch & main power source	
The time needed for each measurement is longer than specified	Pressure at the sample inlet is not high enough	Increase pressure at the sample inlet (warning: do not exceed the pressure rating for the sample inlet)	
Instrument valves do not operate properly	Solenoids are not powered	Confirm that both main and front panel power are switched on.	



# Limited Warranty

**Limited Warranty:** P+E warrants that all products sold shall conform to the P+E's standard specification for products, subject to reasonable manufacturing tolerances, for a period of one year for complete analytical systems. This warranty covers the electronics and the palladium cells against failure due to defects in materials and workmanship. Standard components and subsystems such as valves, fittings, instruments, controllers, etc. which are provided as an integral part of the products, will be guaranteed to the extent of the warranty offered by that manufacturer. The warranty coverage period starts from the date of shipment. This warranty excludes damage resulting from improper operation or misuse. This warranty does not extend to the process of manufacture nor to the quality of any other components, processes, facilities or equipment which are not supplied by P+E and in connection with which the product is to be used, and Purchaser shall hold P+E harmless from any suit, claim or damage, arising from or out of the use of this product. P+E shall not be responsible for work done, material furnished or repairs made by others unless agreed upon in writing, and reserves the right of doing or supervising any necessary repair work incident to putting products in proper operation. Purchaser agrees to use reasonable care in the operation and maintenance of products provided in accordance with instructions furnished by P+E.

# **Procedures for Obtaining Warranty Service**

1. Contact your P+E distributor or call Power & Energy, Inc. to obtain a return merchandise authorization (RMA) number within the applicable warranty period. Power & Energy, Inc. will not accept any returned product without an RMA number.

2. Ship the product to Power & Energy, Inc., freight prepaid, together with your bill of sale or other proof of purchase, your name, address, description of the problem(s). Print the RMA number you have obtained on the outside of the package.

# This device has been tested for electromagnetic emissions and immunity and has been found to be in compliance with the following directives for class A equipment:

EN 62500-6-2:2002

EN 55011:2000

# This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this device in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his or her own expense.

# **Safety Information and Precautions**

# Service by Qualified Personnel Only

Operating personnel must not remove the instrument's cover. Component replacement, servicing, or calibration must be performed by qualified individuals, preferably Power & Energy <sup>™</sup> technicians. Improper disassembly may contaminate the plumbing inside the analyzer.

# **Use Caution When Handling Flammable Gases**

Observe proper safety precautions and local regulations for the handling of flammable gases.

# **External Devices**

All External devices that connect to this unit, including those suggested in this manual, must have fittings and usage consistent with the intended use of this product and the handling of hydrogen.

# **Connections**

All connections to this unit must be made with proper gas fittings or electrical connectors. Gas connections should be leak-checked during installation.

# **Operate at Safe Pressures**

Adhere to unit specifications and local safety regulations for handling pressurized gases. For safety, a suitable pressure relief valve should be used when inlet gases are pressure regulated from a compressed source.

# **Avoid Contamination**

Do not allow dust, dirt or other contamination to enter the unit before or during use. Standard industry practices should be followed to ensure clean connections to the UPH port on the unit.

# **Temperature and Sunlight Exposure**

Do not operate the instrument in areas where the enclosure is exposed to direct sunlight for extended periods or where the environmental conditions will cause the internal temperature of the instrument to be more than 40 % (104 %) or less than 0°C (32°F).

# Vibration and Shock

Avoid excessive vibration and shocks. The instrument contains securely mounted components, but some of these components may be damaged with excessive vibration or shock.

# **Hot Surfaces**

Do not touch the palladium collection cell with bare fingers. Some components operate at 350°C and can cause injury. Allow half an hour cool down time before servicing the unit.

# **Electrical**

Operate only with proper AC voltage according to the purchase specifications.



# **Mechanical Drawings**







# **Technical Specifications**

# Hydrogen Input:

Recommended Minimum pressure: 95 PSIG / 0.65 MPa Maximum pressure (Do not exceed): 142 PSIG / 0.98 MPa (Japan & Korea) Minimum Purity: 99.97%

# **Operating Temp Range:**

Minimum Temp 32° F – 0° C Maximum Temp 104° F – 40° C

#### **Electrical:**

Voltage 85-265 VAC Frequency 47-63 Hz

#### Size:

Dimensions H 30.5" (775 mm) x W 28.1" (713) x D 22.3" (567) Weight 155 Lbs. (70 kg)



# **APPENDIX**

# **Data Quality and Sensitivity**

The plot of some of the data are shown in the below figure, where the data are having low signal to Noise ratio and having a high sensitivity of ppb level measurements. (For more data, contact P+E)













N2 at 25 ppm









#### N2 at 150 ppm











N2 at 100 ppm











# Ar

Ar at 100 ppm



Figure 37 : FILAMENT B



Figure 38 : Ar at 100 ppm



**CO** 

CO at 50 ppb



Figure 39 : FILAMENT B



Figure 40 : CO at 50 ppb



#### CO at 200 ppb











CO at 300 ppb











# H2S,COS & CS2







# Figure 46 : FILAMENT A













#### H2S, COS at 20 ppb







Figure 50 : H2S at 15 ppb

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# CH4

CH4 at 6 ppm



Figure 53 : FILAMENT A



Figure 54 : CH4 at 6 ppm



# **CO2**

CO2 at 2 ppm



Figure 55 : FILAMENT A





#### CO2 at 4.4 ppm











# NOTES


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