

## Itemized Product Description(s)

Below is a description of products and individual components offered by Fuel Cell Technologies, Inc. Some products may be viewed on our website at <http://www.fuelcelltechnologies.com/>. Abbreviations refer to components of the Fuel Cell Technologies Testing Station and the station itself is denoted by the acronym FCT-TS. The testing station and associated options are described as follows:

### **Fuel Cell Testing Station (see Fig. 6)**

- The station provides control of flow, temperature, humidity, and pressure for the anode and cathode gases. The station incorporates a DC electronic load and a “Zero Volt Loading” power supply that allows testing of single cells down to Zero (0) Volts. Cell stacks may be tested up to the maximum wattage of the DC load. A computer utilizing LabView-based software gathers and plots data for I-V curves, life-cycle tests, a reference electrode, and an optional AC-Impedance measurement system. Further description of each individual item contained in the FCT-TS are listed below:
- **Anode Gas (AG)**
  - A five-way valve allows the selection of up to three separate gases plumbed into the rear of the FCT-TS. The associated label identification is “HYDROGEN”, “REFORMATE”, “NITROGEN PURGE” located on the front panel. A mass flow controller (or rotometer) controls the gas flow from a minimum of 10 sccm to a maximum of 500 sccm (Note: these values are specified by the customer). A valve may be switched to either “BYPASS” or “HUMIDITY” to control the flow of the anode gas stream. The humidity bottle is temperature controlled from ambient to 100°C (or higher with backpressure) to provide variable humidification. The humidification is obtained by passing the gas stream through Nafion tubing located inside the humidity bottle. The output of the fuel cell may be backpressured from 1 atmosphere to 70 psi by manually controlling a Tescom Backpressure Regulator. The anode gas stream is then directed out through the rear panel and plumbed to an outdoor vent. The reformat gas is pre-mixed and controlled by a digital mass flow controller (or rotometer) that has been calibrated for hydrogen. The correction factor for reformat is input into the software setup.
- **Cathode Gas (CG)**
  - A five-way valve allows the selection of two gases that are plumbed into the rear of the FCT-TS. The associated label identification is “OXYGEN” and “AIR” located on the front panel. A mass flow controller (or rotometer) controls the gas flow from a minimum of 10 sccm to a maximum of 1000 sccm (Note: these values are specified by the customer). A valve may be switched to either “BYPASS” or “HUMIDITY” to control the flow of the cathode gas stream. The humidity bottle is temperature controlled from ambient to 100°C (or higher with backpressure) to provide variable humidification. The humidification is obtained by passing the gas stream through Nafion tubing located inside the humidity bottle. The output of the fuel cell may be backpressured from 1 atmosphere to 70 psi by manually controlling a Tescom Backpressure Regulator. The cathode gas stream is then directed out through the rear panel and plumbed into a vessel to collect the excess water vapor. The cathode gas flow is controlled by a digital mass flow controller (or rotometer) that is included as standard with the basic system.

- **Humidity Bottle with Auto-Fill (HB/AF)**
  - The FCT Humidity Bottle is made from type 316 stainless steel. Swagelok fittings for gas inputs and outputs are welded into the bottle to allow for maximum flow. Nafion tubing, inserted into a type 316 stainless steel spring for support, is coiled in the bottle to provide near dew-point humidity level for the gas passing through the tubing. The bottle is insulated and heated using a specially designed silicone flex-pad. A magnetic switch, coupled with delay relays, provides automatic filling of the humidity bottle using a metering pump located in the FCT-TS.
  
- **Cell Temperature Control (CTC)**
  - The cell temperature is accurately monitored with a thermocouple that is secured into the thermocouple well located in the fuel cell under test. This device is plugged into the front panel of the FCT-TS. An AC outlet, also located on the front panel, provides a connection for a cartridge heater, or other heating device, to control the cell temperature. The controller's alarm is designed to provide automatic shutdown of all heaters and the flow of Cathode Gas (CG) while simultaneously switching the Anode Gas (AG) from Hydrogen to Nitrogen gas as a safety precaution.
  
- **Electronic Load (EL)**
  - An Agilent Technologies (HP), or equivalent, DC Electronic Load is supplied with each FCT-TS according to the requirements of the customer's fuel cell testing application. The current ratings of the various available loads are:
    - 10A
    - 60A
    - 120A
    - 240A
    - 360A
    - 2000A
    - 4000A

(Note: this variety provides a power range of 10mW up to a maximum of 5.4KW; The EL communicates with the system via a GPIB IEEE-488 interface)
  
- **Temperature Control (TC)**
  - The temperature controller incorporates a specially designed microprocessor to supply precision temperature control over a wide range of conditions. Type "T" thermocouples, provide maximum sensitivity over the operating temperature range of the fuel cell and humidity bottles. If mass flow controllers are ordered as an option, then the thermocouple controller(s) can be set via an RS-485/RS-232 interface.
  
- **Safety**
  - Fail-safe solenoid valves will automatically shut off the Cathode Gas (CG) flow and switch the Anode Gas (AG) flow to Nitrogen, particularly in the event of an over-temperature condition within the operating fuel cell. The over-temperature differential may be adjusted using the fuel cell thermocouple controller. The humidity bottle(s) and cell heater(s) will simultaneously shut down. The FCT-TS may be configured for an automatic (or manual) reset using the fuel cell temperature controller(s). An explosive gas detection system may be utilized as an additional safety device. Up to four modules and sensors may be installed at various locations throughout the hydrogen gas supply and vent paths. Please contact your facilities manager or safety representative for further safety requirements.

## FCT-TS Options

- **Mass Flow Controller(s) (MFC)**
  - The digital mass flow controller provides precision control of gas flow and automatic flow-tracking of a set stoich on both the anode and cathode streams. This option includes the power supply, cables, communications, and associated software. Additional mass flow controllers may be added to mix reformat, add CO poison, and air bleed.
  
- **AC-Impedance (AC-Z) Measurement System (see Fig. 1)**
  - Integrated measurement capability to determine the cell (or stack) DC resistance and the reactive component as a function of frequency during IV curves and life-cycle tests. Measurement options are for:
    - Single cells
    - 6-cell stack,
    - 29-cell stack.
  - The frequency range of the system is 100mHz (0.1Hz) to 10KHz (10,000Hz). Plotting functions include the Nyquist and Bode (magnitude) curves.
  
- **Automatic Backpressure (AB/P)**
  - This feature replaces the manual Tescom Backpressure Regulators with a computer-controlled system that includes a pressure transducer, controller, and a proportional valve that provides automatic pressure control at any flow rate
  
- **Output Tube Line Heater (OTLH)**
  - This product consists of two silicone rubber line heaters with controllers specially designed to heat the anode and cathode gas streams between the humidity bottle and fuel cell to prevent condensation.

## Additional Products

- **Single Cell Hardware (SCH); see Fig. 4 (5 Sq. Cm) & Fig. 5 (50 Sq. Cm.)**
  - A Fuel Cell Hardware Assembly consists of a pair of Poco Graphite Blocks with a precision, machined flow-pattern (pattern is serpentine unless otherwise specified by the customer), and a pair of gold-plated connectors fastened with aluminum end plates. Gas inputs and outputs are through Swagelok fittings. A thermocouple well and two cartridge heaters are also provided. The Poco Graphite Blocks are included in the listed price for 5, 10, & 16 Sq. Cm. (square centimeter) cell hardware and priced according to size for the 25, 50, 100, & 250 Sq. Cm. cell hardware. A single Anode Reference Electrode is included in the listed price.
    - 5cm<sup>2</sup>
    - 10cm<sup>2</sup>
    - 16cm<sup>2</sup>
    - 25cm<sup>2</sup>
    - 50cm<sup>2</sup>
    - 100cm<sup>2</sup>
    - 250cm<sup>2</sup>

- **Individual Humidity Bottle Assembly (HBA) (see Fig. 2 & Fig. 3)**
  - Humidity Bottle Assembly (HBA); Includes: Nafion Tubing, Flex-Heater, Insulation, Thermocouple, and Float-Switch
  
- **Humidification Systems (see Fig. 2 & Fig. 3)**
  - Humidification System (HS); Includes 2 HBA's with Sight Glass & 2 Humidification Controllers (see item #6f) mounted in a specially designed cabinet
  
  - High Performance Dew-Point HS; Includes all components listed in Humidification System with two separate heaters & controllers for dual-zone heating
  
  - Humidification Systems can include Automatic Water-Fill, and/or Manual Backpressure
  
- **Stand-Alone Temperature Controller (S-AT/C)**
  - This controller is mounted in an extruded aluminum Pomona ® box with a power switch, AC connectors, and a thermocouple jack with associated type “T” thermocouple. This compact unit has a solid-state relay output rated at 3.5A.
  
- **Conductivity Cell (CC)**
  - This particular cell is specially designed with Kel-F plastic and supplied with Platinum ribbon contacts for measurement of cell membrane conductivity.

**Overall System Operating Parameters** Note: Each system is designed to operate under a specific set of operating conditions that are as follows:

- |                            |   |
|----------------------------|---|
| • Current Range            | OA – Load box rating                                    |
| • Cell Voltage             | 0V – 60V  |
| • Reference Electrode      | 0V – 2V   |
| • Cell Temperature Control | Ambient to 150°C  |
| • Anode Humidifier         | Ambient to 120°C  |
| • Cathode Humidifier       | Ambient to 120°C  |
| • A&C Backpressure         | Zero to manifold pressure                               |
| • Anode Flow Rate          | 10sccm 1.4 times Range (Digitally controlled via MFC's) |
| • Cathode Flow Rate        | 10sccm 1.4 times Range (Digitally controlled via MFC's) |
| • Relative Humidity        | Bypass to near dew-point at full flow                   |

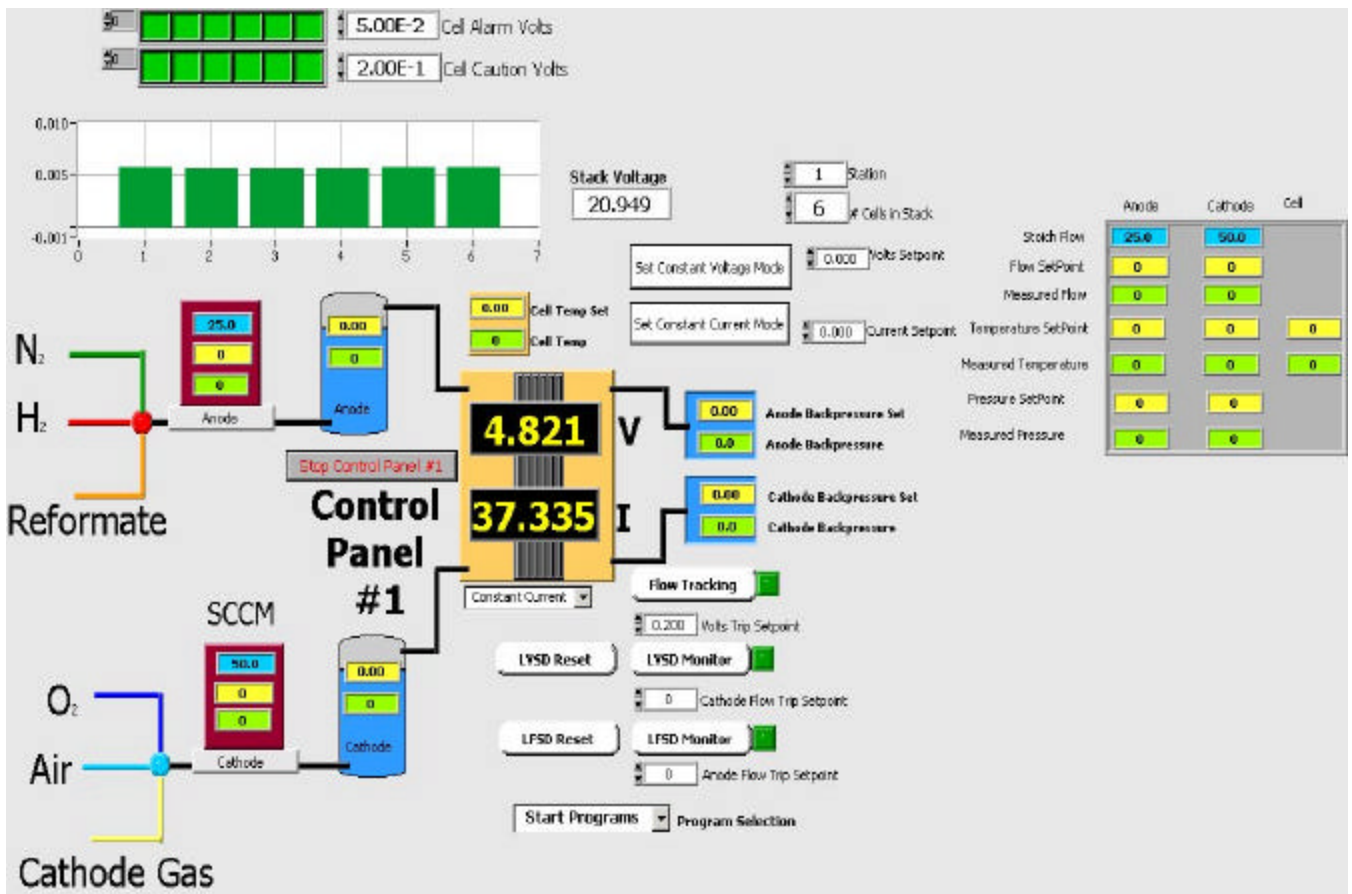


Figure #1



Figure 2

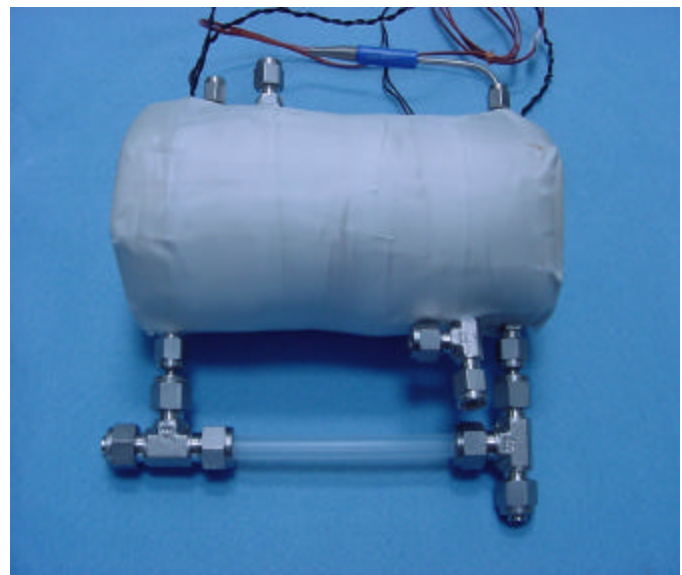


Figure 3

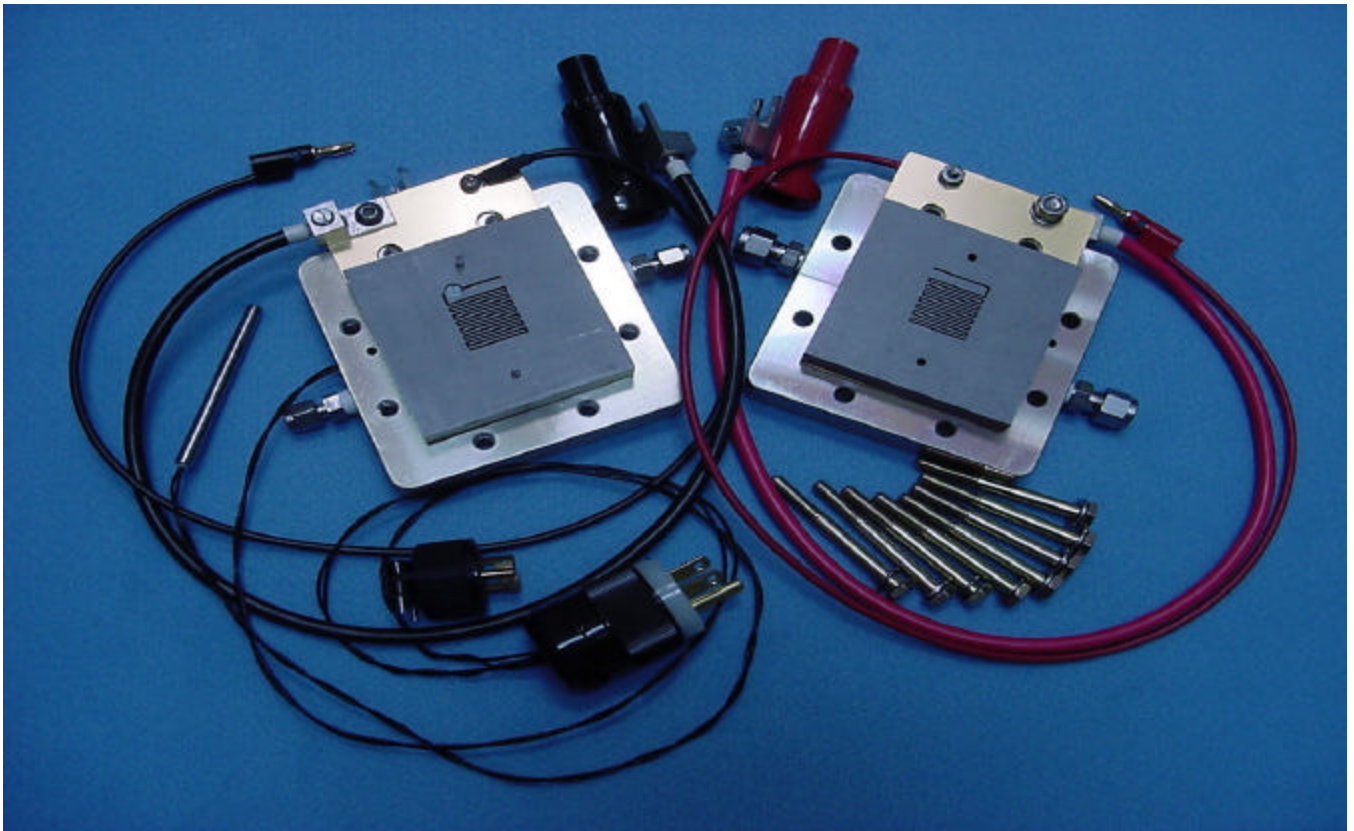


Figure 4

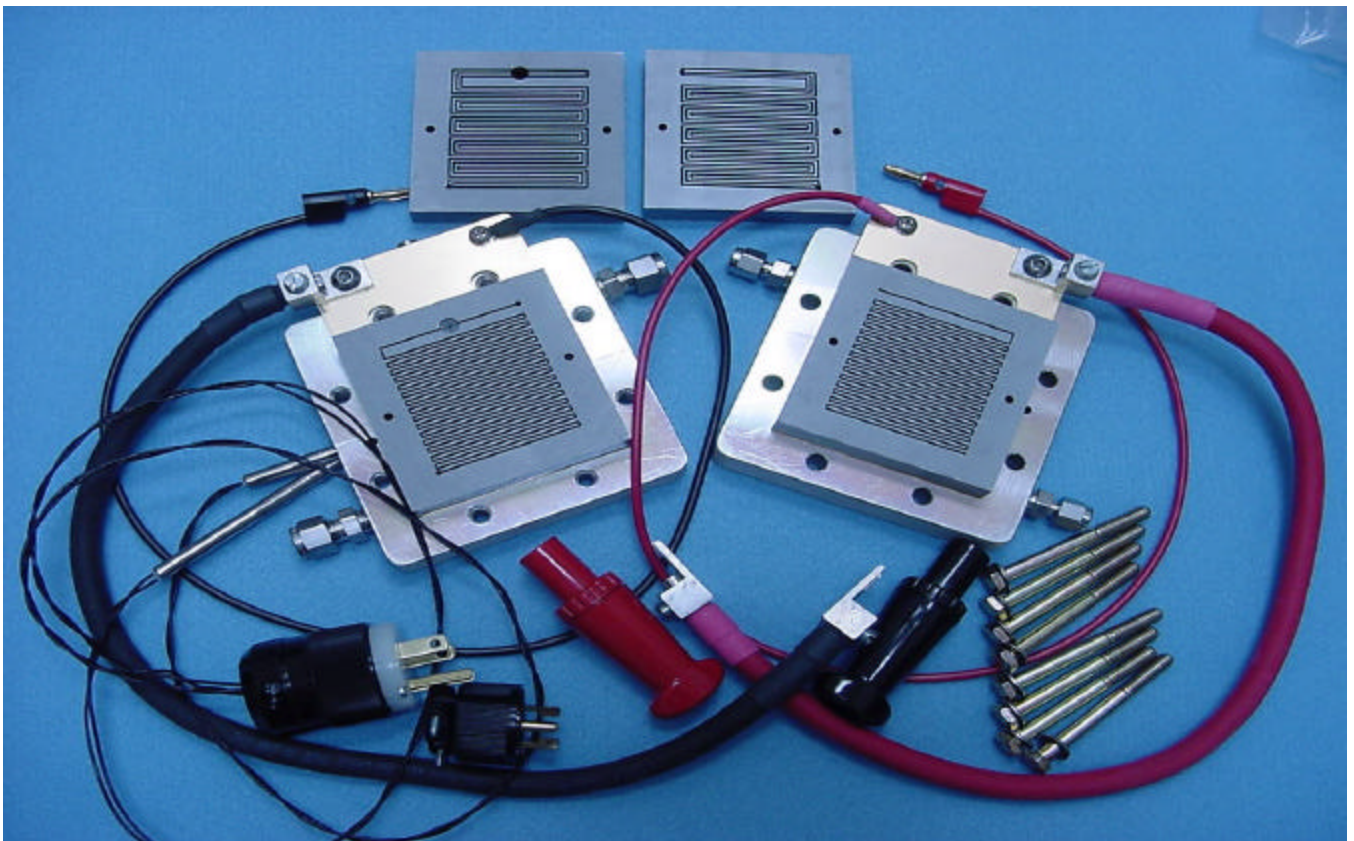


Figure 5



Figure 6