

Fuel Cell Test Station

- First debuted in 1997, Arbin noticed a growing need for quality fuel cell testing capabilities in the market
- Combines several proprietary technologies to provide a completely automated solution for fuel cell research in a compact foot print
- We now offer a logical range of FCTS adaptations for each power levels, ranging from 10W – 100kW for PEM, DM and SOFC fuel cells



Fuel Cell Test Station "Options"

50W DM
28" x 40" x 59"



200W PEM
28" x 40" x 77"



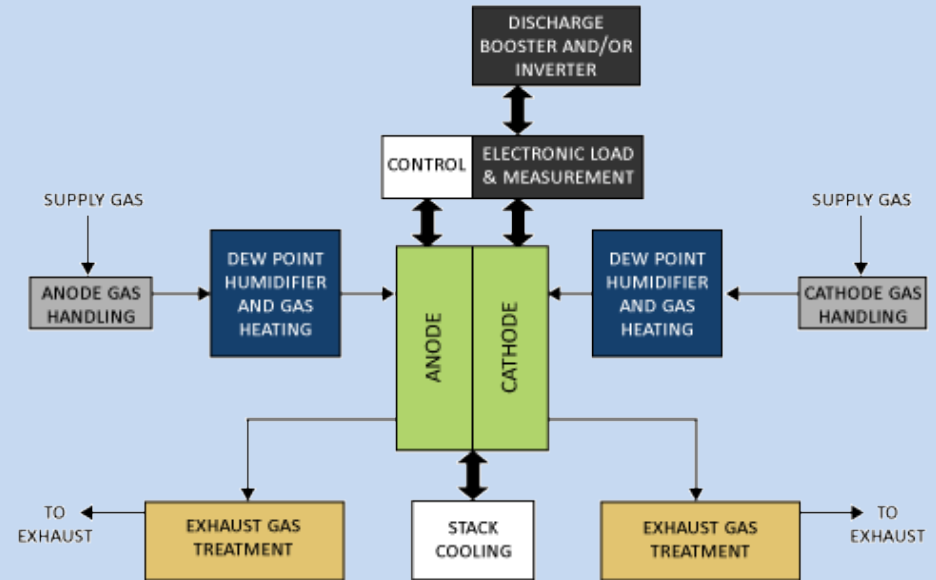
1kW PEM & DM
40" x 50" x 77"



20kW PEM & DM
40" x 80" x 77"

Fuel Cell Test Station - Functions

- Input Gas Handling
- Liquid Reactant Handling
- Dew Point Humidifier
- Exhaust Gas Treatment
- Stack Cooling/Heating
- Electronic Load
- Software, Control and DAQ
- Arbin's FCTS incorporates a two level safety system:
 - Module level & Overall system level
 - The two levels work together to make FCTS extremely safe to operate both to the user and to the system



Input Gas Handling (IGH) Module

- High accuracy and fast response time
 - Standard flow rate accuracy is 1% full scale with a 50:1 turndown ratio
 - Flow rate response time is 2 seconds when in non-ramping operation
- Automatic function for set-and-forget operation
 - All input gasses are controlled via PC with Arbin's Mits Pro Software
- Proprietary mixing system with backflow prevention
- Automatic N₂ Purge
 - Controlled by the central safety system with automatic operation and a fail-open operation
- Ability to control molar flow rate with stoic control



Input Gas Handling (IGH) Safety

- Hydrogen sensor and alarm
- Toxic gas sensor and alarm
(standard if FCTS is equipped with a CO line)
- Automatic Fail-Safe(fail-open) purge system
- Fail-safe (fail-closed) oxidant and fuel gas control
- User Intervention for safety override



Combustible gas sensor

Liquid Reactant Handling Module

- Consists of a liquid reactant recirculation loop with:
 - Heating/cooling capability
 - Pressure control
 - Flow rate control
 - Level Control
- Automatic level control, fed to the cell or stack via PC controlled piston or gear pump
- User selects recirculation or single pass type operation
- Automatic product gas venting
 - Vents off any built up product gas such as CO₂
- Low power stack/cell cooling when not in operation
- Composition sampling port
- Quick drain and purge to facilitate quick changing of liquid fuels



Safety

- Over temperature shut down
- Over pressure shut down
- Module monitored by overall safety system

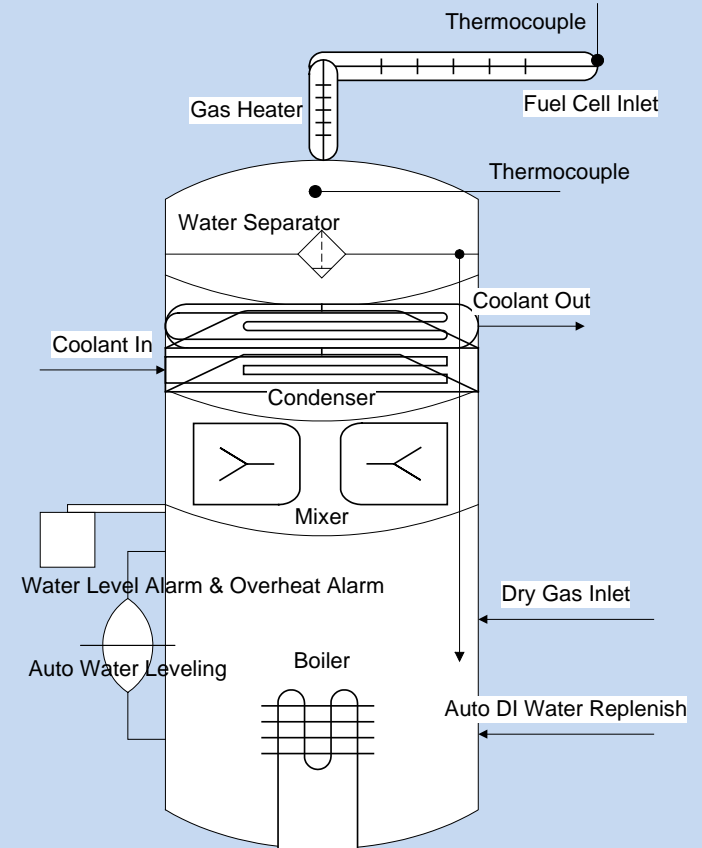
Dew Point Humidifier Module

- Accurately controls the passing gas dew point temperature, which is the only effective way to control gas humidity
- Automatic water level and replenishment to provide stable humidity for long period testing
- Compact and simple structure
 - User does not have to set-up separate boiler, bubbler and condenser
- Dry Gas Bypass
 - Software controlled bypass, gas temperature still controlled
- Dynamic Range
 - Wide flow range – turndown ratio better than 100:1, allows stack and cell testing with single tester
- 4 zone PID control for temperature



Dew Point Humidifier

- Wide dew point temperature range
+20 to 95°C (standard) and up to 140°C (optional)
- Wide gas temperature range
Max Temp: 100°C(standard) up to 150° C (optional)
- High Accuracy: ± 0.5 °C typical dew point control accuracy
- Fast Response Time: 5-10 °C per minute on temperature set point change
- High stability
Even during periods of changing flow rates, temperature or humidity
- >90% efficient
- Automatic DPH coolant flow rate control
- Heated Transfer Lines



Safety

- Water level sensor and alarm
- Over/Under Temperature alarm

Stack Cooling / Heating Module

- A common but optional module, it allows accurate temperature control using a liquid coolant
- Can be used to keep high power stacks cool, or heat a stack to operating temperature
- Temperature Control Range
 - Range from the coolant temperature plus 20°C up to 90°C at atmospheric pressure
- Temperature accuracy: 2°C or better (Typically 1°C)
- Temperature rise time: between 1-3°C/min depending on the heat transfer properties of stack
- Automatic replenishment
- Turndown ratio: flow rate controllable with turn down ratio of 20:1 and response time <5seconds
- Supports various coolant types
- Built in water filter
 - A coolant filter is included in the recirculation loop to protect the fuel cell/stack

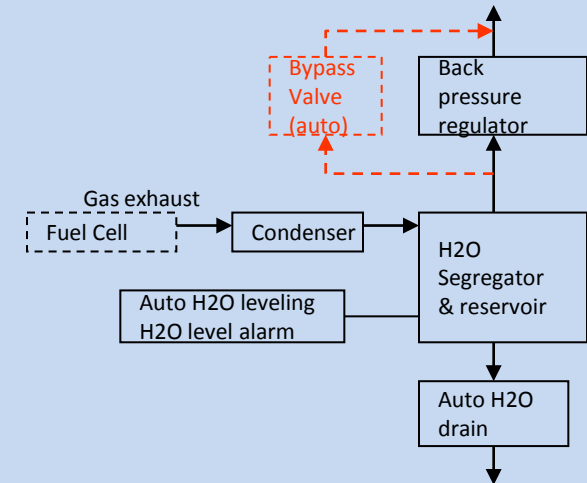


Safety

- Over/Under temperature alarm
- Low level alarm
- Low flow rate shut off and alarm
- Self correcting overpressure system

Exhaust Gas Treatment Module

- Handles the exhaust gas leaving the fuel cell
- Consists of a gas-water segregation system which cools the exhaust and back pressure controller
 - Water is removed from the exhaust gas stream for better back pressure control
 - Water is then drained automatically and can be metered for water balancing(option)
- Controls the operating pressure for the cathode and anode side
 - Completely automatic and software controlled
- User can define pressure ramps or steps, as well as have system react to some other system parameter such as cell voltage
- Water level maintained to ensure proper operation and employs automatic water draining
- Fast response time: Pressure response time is 2 seconds or faster unless in ramping operation where the user specifies the pressure change rate
- High Stability and smooth operation without pressure interruption



Electronic Load Module

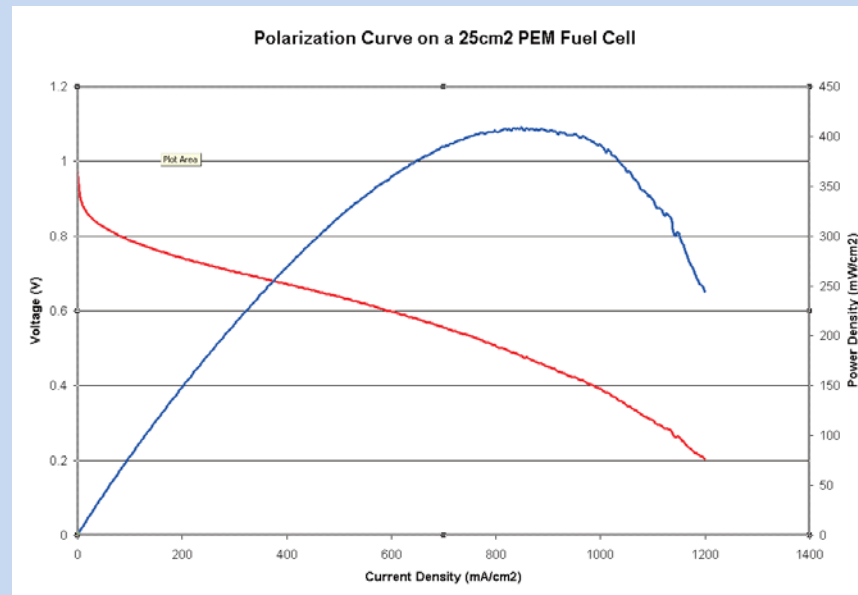
- Current, Voltage and Power Control
- Handles OCV, CC, CV, CP, CR, Voltage and current ramps (polarization curve).
- Custom configuration
- User defined current and voltage ranges
 - 3 Current ranges for higher accuracy
- Automatic and programmable control
- 0V cut off to prevent negative voltage on sample



Common Applications

- Polarization Curves

Find the optimal operating point and performance characteristics of the FC

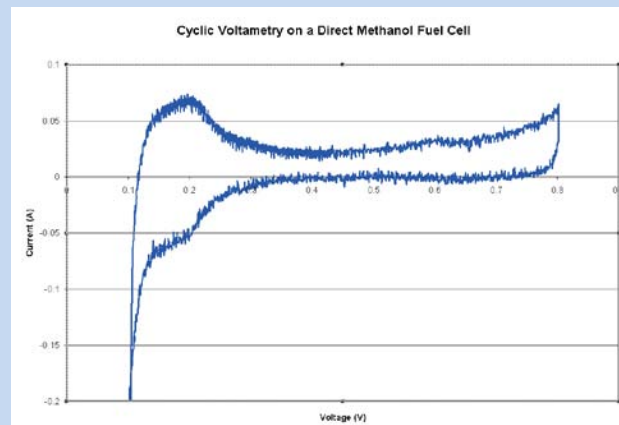


- Internal Resistance Measurements

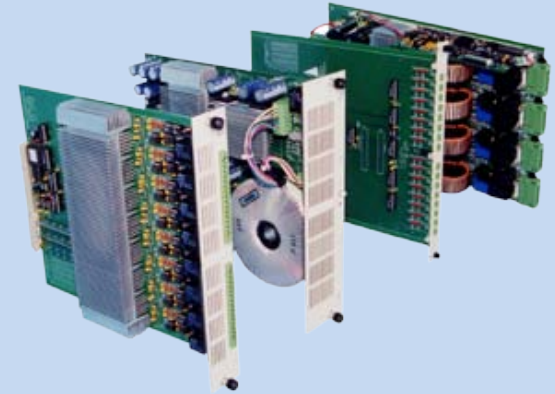
Using current interrupt method, Arbin FCTS systems can measure the DC Internal Resistance and use the collected data to control the test

Common Applications

- Lifetime Testing
 - Apply a constant current discharge on the FC until the voltage drops by 10% or out of acceptable range
- Stoichiometric Control
 - Allows users to set proper gas ratios and the system will scale flowrates accordingly
- Cyclic Voltammetry
 - Provides insight into the fuel cell reaction kinetics and characterize fuel cell catalyst activity in greater detail



Optional Auxiliaries



- **Auxiliary Voltage Input:** Usually a floating $\pm 10\text{V}$ range with $10\text{G}\Omega$ input impedance
- **Thermocouple Input:** Type T, K, J, E
- **Thermistor Input:** Provides activation signal for the thermistor
- **Pressure Input:** Provides activation signal to the pressure transducer
- **pH meter:** A BNC connector is provided for input from the pH sensor
- **External Charge/Load Adapter:** This option is to test a battery under a specific charger/load or to test the charger/load. It connects the battery under test to an external charger or load.
- **Smart Battery:** The BT2000 reads information from a smart battery and tests the smart battery accordingly
- **Flow Rate Input:** Reads data from the gas or liquid flow meter into data file
- **Programmable Digital Input/Output Control:** Input control provides external TTL or relay signal to control the testing while output control provides TTL or isolated relay output to trigger external devices such as valves or alarm.

Optional Utilities

- **Auto-Calibration** allows for automatic calibration of the main I/V channels and auxiliary inputs for higher number-of-channel systems
- **Uninterruptible Power Supply (UPS)** protects against computer shutdown in the event of power failure. Arbin recommends a UPS for the system's protection.
- Software can control multiple **Temperature Chambers** which are added to the system to provide environmental control around tested cell/battery.
- **AC Impedance Measurement** to achieve certain accuracy ($\pm 5\sim 6\%$ of value) of the cell's AC impedance.
- **Temperature chamber or device controller** to control Arbin temperature chamber or other brands of temperature chamber.
- **Mass flow or metering pump controller** to deliver required flow rate set in the testing schedule and record flow rate data in a data file.
- **Combustible or toxic gas detector and alarm.**



MITs Pro 5.0 for FCTS

- **Menu Driven User Interface**
- **Multiple Zone PID**
Precise control over a wide range of test parameters
- **Stoichiometric Control**
Allows users to set proper gas ratios and the system will scale flowrates accordingly
- **“On the Fly” Test Modifications**
Make changes to a running test without stopping, pausing, or restarting

<Schedule File Window> AB-TPID-Coolant.sdu -

File Edit Print View Settings Help

Test Setting Index	Test Setting Label	Number Of Elements	Resumable						
1	FH_T40	9	<input checked="" type="checkbox"/>						
	Element Index	Type	Aux Index-Nickname	Turn On	Ctrl Value 1	Ctrl Value 2	Ctrl Value 3	Wait Until Hit	Tolerance(+/-)
	Element 1	Temperature	1 - O_DPT	<input type="checkbox"/>					
	Element 2	Temperature	2 - O_GST	<input type="checkbox"/>					
	Element 3	Temperature	3 - F_DPT	<input type="checkbox"/>					
	Element 4	Temperature	4 - F_GST	<input type="checkbox"/>					
	Element 5	Temperature	5 - SC_ST	<input checked="" type="checkbox"/>	(C): 40			<input type="checkbox"/>	2
	Element 6	Temperature	7 - FC_T	<input type="checkbox"/>					
	Element 7	Flowrate	1 - Air_FR (5slpm)	<input type="checkbox"/>					
	Element 8	Flowrate	2 - H2_FR (3slpm)	<input type="checkbox"/>					
	Element 9	Flowrate	3 - SC_FR (2 lpm)	<input checked="" type="checkbox"/>	(slpm): 1	Stoich: 0	(slpm): 0	<input type="checkbox"/>	2
2	FH_T60	9	<input checked="" type="checkbox"/>						
	Element Index	Type	Aux Index-Nickname	Turn On	Ctrl Value 1	Ctrl Value 2	Ctrl Value 3	Wait Until Hit	Tolerance(+/-)
	Element 1	Temperature	1 - O_DPT	<input type="checkbox"/>					
	Element 2	Temperature	2 - O_GST	<input type="checkbox"/>					
	Element 3	Temperature	3 - F_DPT	<input type="checkbox"/>					
	Element 4	Temperature	4 - F_GST	<input type="checkbox"/>					
	Element 5	Temperature	5 - SC_ST	<input checked="" type="checkbox"/>	(C): 60			<input type="checkbox"/>	2
	Element 6	Temperature	7 - FC_T	<input type="checkbox"/>					
	Element 7	Flowrate	1 - Air_FR (5slpm)	<input type="checkbox"/>					
	Element 8	Flowrate	2 - H2_FR (3slpm)	<input type="checkbox"/>					
	Element 9	Flowrate	3 - SC_FR (2 lpm)	<input checked="" type="checkbox"/>	(slpm): 1	Stoich: 0	(slpm): 0	<input type="checkbox"/>	2
3	FH_T80	9	<input checked="" type="checkbox"/>						
	Element Index	Type	Aux Index-Nickname	Turn On	Ctrl Value 1	Ctrl Value 2	Ctrl Value 3	Wait Until Hit	Tolerance(+/-)
	Element 1	Temperature	1 - O_DPT	<input type="checkbox"/>					
	Element 2	Temperature	2 - O_GST	<input type="checkbox"/>					

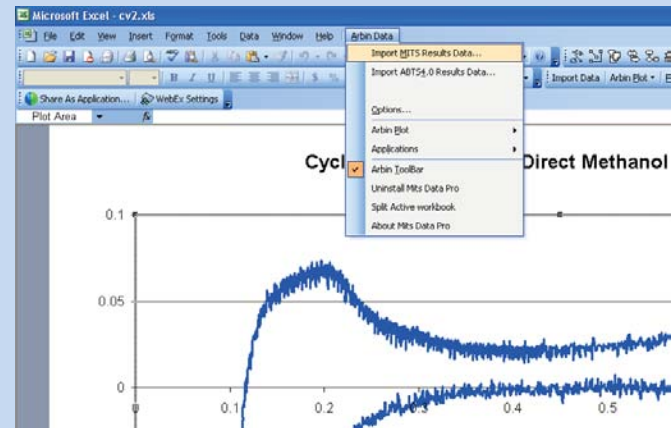
MITs Pro 5.0 for FCTS

- **Real time variable monitoring and control**
Allows quick access to useful information
- **Logical Commands**
Makes it highly flexible
- **Data Watcher**
- **Quick and Simple data importing in MS Excel**
- **Comprehensive programmable operating conditions**

<Monitor & Control Window> ArbinSys.bth -

File Edit Print View Control Graph Settings Help

(0)1	Channel Params	Present Values	Environment Params	Present Values	Background Settings
	Channel Index	1	O_DPT	0.0000 (C)	OFF
	Test Name		O_GST	0.0000 (C)	OFF
	Schedule Name		O_BP (100psig)	0.0000 (PSI)	OFF
	Status		Air_FR (5slpm)	0.0000 (sccm)	OFF
	Step Index	1	OxI_Purge valve	0 - OFF	-
	Cycle Index	1	O_Humid ON/OFF	0 - OFF	1 - ON
	Step Time (s)	00:00:00	F_DPT	0.0000 (C)	OFF
	Test Time (s)	00:00:00	F_GST	0.0000 (C)	OFF
	Exit Condition	N/A	F_BP (100psig)	0.0000 (PSI)	OFF
	Voltage	0.0000 (uV)	H2_FR (3slpm)	0.0000 (sccm)	OFF
	Current	0.0000 (uA)	Fuel Purge valve	0 - OFF	-
	Current Density	0.0000 (uA/cm2)	F_Humid ON/OFF	0 - OFF	1 - ON
	Power	0.0000 (uW)	SC_ST	0.0000 (C)	OFF
	Power Density	0.0000 (uW/cm2)	SC_RT	0.0000 (C)	-
	Internal Resistance	0.0000 (uOhm)	FC_T	0.0000 (C)	OFF
	AC_Impedance	0.0000 (uOhm)	SC_FR (2 lpm)	0.0000 (sccm)	OFF
	ACI_Phase_Angle	0.0000 (deg)			



MIT Pro, Control & DAQ Module

- **Software Control**

- Constant Current
- Constant Voltage
- Constant Load
- Constant Power
- Current and Voltage Ramps
- Current and Voltage Staircases
- Current and Voltage Pulses
- Current and Voltage Output based on user defined formula

- **Background Parameters**

- System Temperatures
- System Pressures
- System Gas and Liquid Flow Rates
- Dew Points

MITs Pro, Control & DAQ Module

Data Logging:

– *Stack Cooling/Heating Module (SCH)*

- Stack Cooling: Coolant Temperature In to Stack
- Stack Cooling: Coolant Temperature Out of Stack
- Stack Cooling: Coolant Pressure In/Out (optional)
- Stack Cooling: Coolant Flow Rate

– *Electronic Load Module (ELOAD)*

- Data Point
- Test Time
- Date Time
- Step Time
- Step Index
- Cycle Index
- Cycle Time
- Stack Voltage
- Stack Current
- Discharge Energy
- Discharge Capacity
- dV/dt
- Internal Resistance

- The interval between data points can be set by increment of time, voltage and current.

Software: Writing a Test Schedule

<Schedule File Window> AB-D-Burn-in-maxV-maxP.sdu -

File Edit Print View Settings Help

	Step Label	Number Of Limits	Control Type	Control Value	Extra Control Value 1	Extra Control Value 2	Current Range	Extended Definition	Extended Definition 1	Test Settings		
1	✖ Step_A	2	Rest							W_Up		
	Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2	Sign2	Value2	Type3	Sign3	Value3
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_St	>=	00:00:10						
2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:00:05						
2	✖ Step_B	2	Current(A)	-3.4			High			Step 2		
	Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2	Sign2	Value2	Type3	Sign3	Value3
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_St	>=	00:10:00						
2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:00:30						
3	✖ Step_C	2	Current(A)	-8.5			High			Step 2		
	Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2	Sign2	Value2	Type3	Sign3	Value3
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_St	>=	00:10:00						
2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:00:30						
4	✖ Step_G	2	Current(A)	-13.6			High			Step 2		
	Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2	Sign2	Value2	Type3	Sign3	Value3
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_St	>=	00:30:00						
2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:00:30						
5	✖ Step_E	2	Current(A)	-17			High			Step 2		
	Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2	Sign2	Value2	Type3	Sign3	Value3
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	End Test	PV_CHAN_St	>=	01:00:00						
2	<input checked="" type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:00:10						

Global Step / Limit Formula Test Settings

[2010-01-28, 18:09:51] Succeeded to save schedule file "C:\ArbinSoftware\MITS_PRO\Work\AB-D-Burn-in-maxV-maxP.sdu"
 [2010-01-28, 18:09:51] Connecting to control module 1...
 [2010-01-28, 18:09:51] Succeeded to reload schedule file "C:\ArbinSoftware\MITS_PRO\Work\AB-D-Burn-in-maxV-maxP.sdu" to control module 1.

Done 2010-01-28 18:10:35 PM

Schedule Writing

<Schedule File Window> LiBattery.sdu -

File Edit Print View Settings Help

Copy

		Step Label	Number Of Limits	Control Type	Control Value	Extra Control Value 1	Extra Control Value 2	Current Range
3	✘	Step_E	3	Voltage(V)	4.15			DEFAULT
		Log Limit	Step Limit	Goto Step	Type1	Sign1	Value1	Type2
1	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_Current	<=	0.05	
2	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Next Step	PV_CHAN_Test_Time	>=	03:00:00	
3	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		DV_Time	>=	00:01:00	

1. Control Type.
2. Control Value
3. Termination Condition
4. Data Collection Condition

Software: Results File

Import Data Dialog:

- Import File Name: C:\ArbinSoftware\MITS_PRO\Data\GSM-5A.res
- Test Name: GSM-5A
- Channel Index: 1-005, 1-006, 1-007, 1-008
- Apply Filter to Normal Channel Data:
 - All
 - First 10 Percent
 - Last
 - Cycle No. 1 To Cycle 1
 - From Step 1 To Step 1
 - From Cycle 1 To Cycle 1
 - From Point 1 To Point 100
- Import Data Options:
 - Normal Channel Data
 - Split 2nd Voltage
 - Auxiliary Channel Data
 - Statistics Channel Data
 - SmartBattery Data
- Output File Name: C:\ArbinSoftware\DataPro\GSM-5A.xls

Simple Plot Dialog:

- Channel Plot
- Select Axes:
 - X: Data_Point, Test_Time(s), Date_Time, Step_Time(s)
 - Y1: Data_Point, Test_Time(s), Date_Time, Step_Time(s), Step_Index, Cycle_Index
 - Y2: Date_Time, Step_Time(s), Step_Index, Cycle_Index, Current(A), Voltage(V), Charge_Capacity(Ah)
- Select Channel: From 5 To 5
- Select Cycle_Index: From 1 To 1
- Plot on:
 - Default chart
 - Chart Per Channel
 - New chart (Channel_Chart_1)
 - Add to the chart plotted last time
- Plot Style: ScatterLinesNoMarkers

- Results files directly in Access / Excel format
- Simple macro to automate graphs
- Simple data analysis

Software: Data Analysis & Manipulation

Data Analysis is Easy w/ Included Software and Macros

