User's Manual

KFM Series
Application Software

FCTester
Ver. 1.1

KIKUSUI
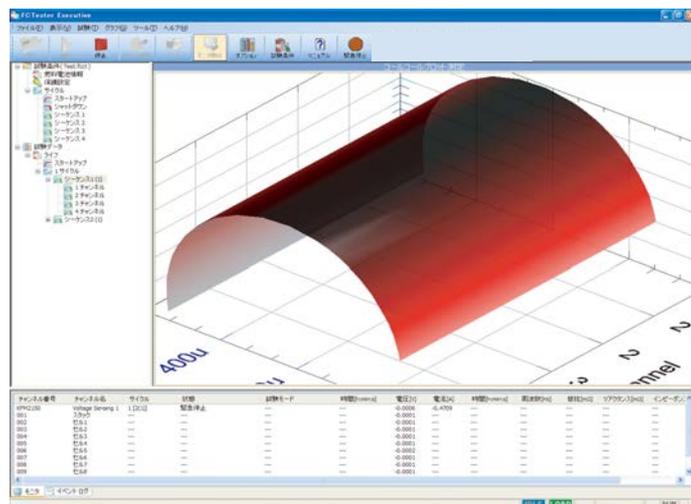
Use of This Manual

Please read through and understand this User's Manual before operating the product. After reading, always keep the manual nearby so that you may refer to it as needed. When moving the product to another location, be sure to bring the manual as well.

If you find any misplaced or missing pages in this manual, they will be replaced. If the manual gets lost or soiled, a new copy can be provided for a fee. In either case, please contact Kikusui distributor/agent, and provide the "Kikusui Part No." given on the cover.

This manual has been prepared with the utmost care; however, if you have any questions, or note any errors or omissions, please contact Kikusui distributor/agent.

⚠ **For Safe Use**

Before starting tests using this application software, please thoroughly read the following operation manuals describing the hardware. Use extreme caution to make correct connections and handle the components of the system properly. Improper connections or handling may cause serious accidents such as damage or fire.

- Fuel Cell Impedance Measurement System   KFM2150SYSTEM
- FC Scanner   KFM2151 (when using the scanner)

How to Read This Manual

Preface

Thank you for purchasing the FCTester application software for the KFM2150 FC Impedance Meter.

This manual is intended for first-time users of the application. It describes installation procedures, various settings, basic operations, safety precautions, etc.

Read this manual thoroughly to use the functions of the application software effectively. You can also review this manual when you are confused about an operation or when a problem occurs.

For details on the hardware of the impedance measurement system, read the operation manual of the respective product.

How to read this manual

This manual is designed to be read from beginning to end. We recommend that you read the manual thoroughly from the beginning before using this application software for the first time.

Related manuals

For details on the impedance measurement system, see the respective operation manual of the impedance measurement system.

Intended readers of this manual

This manual is intended for operators that control the impedance measurement system using the KFM2150 or persons teaching other users on how to operate the system.

Structure

Below is the structure of the manual. A summary of each chapter is provided.

Chapter 1   General Description

This chapter gives a general description and introduces the features of the FCTester.

Chapter 2   Setup

This chapter describes the procedures from unpacking to preparation before use.

Chapter 3   System Configuration

This chapter describes the FCTester Configuration Tool (system configuration program).

Chapter 4   Creating Test Conditions

This chapter describes the FCTester Condition Editor (test condition editing program).

Chapter 5   Executing Tests

This chapter describes the FCTester Executive (test execution program).

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Notations

- The word "PC" indicates a personal computer in this manual.
- The KFM2150 FC Impedance Meter is also simply referred to as KFM2150 in this manual.
- The PLZ-4W Series Electronic Load Unit is also referred to as the PLZ-4W or the PLZ-4W Series in this manual.
- The following markings are used in the explanations in the text.

⚠ CAUTION

Indicates a potentially hazardous situation which, if ignored, may result in damage to the product and other property.

NOTE

Indicates information that you should know or convenient tips.

See

Indicates reference to detailed information.

Contents

General Description

This chapter gives a general description and introduces the features of the FCTester.

1.1　Overview

FCTester is a application software used to retrieve measured data from the KFM2150 FC Impedance Meter.

Integrating the FCTester in the KFM2150 impedance measurement system allows additional measurements to be made such as Cole-Cole plot measurements and I-V characteristics measurements. This feature streamlines the fuel cell evaluation tests.

FCTester Version to Which This Manual Applies

This manual applies to FCTester version 1.1X.

You can check the version in the Help menu of the FCTester Condition Editor or Executive.

Main Features

■ Possible test modes
- I-V measurement
- V-I measurement
- I-V + AC impedance measurement
- I-V + Cole-Cole plot measurement
- Cole-Cole plot measurement
- AC impedance measurement
- Current interrupt measurement
- Constant current test
- Constant voltage test

■ Startup operation of the fuel cell
- Startup sequence
- Shutdown sequence

■ Sequence operation of the measurement mode
- Up to 15 sequences

Structure

FCTester consists of the following three programs.

Program	Description
FCTester Configuration Tool (system configuration program)	Configures the FC impedance measurement system. The program is used only when configuring the system for the first time or when you change the system configuration.
FCTester Condition Editor (test condition editing program)	Creates test conditions.
FCTester Executive (text execution program)	Loads test conditions, executes tests, and saves and displays the measurement data.

1.2 System Requirements

The following hardware and software are required to use FCTester.

PC system

- 1 GHz or faster 32-bit (x86) or 64-bit (x64) processor

- 1 GB or more RAM (32-bit) or 2 GB or more RAM (64-bit)

- 16 GB or more available hard disk space (32-bit) or 20 GB or more (64-bit) (additional free space is required to save data)

- DirectX 9 graphics device with Windows Display Driver Model (WDDM) 1.0 or higher driver

- Microsoft Windows 7

- SVGA resolution or higher (800 × 600 dots or higher).

- CD-ROM drive.

- Mouse or pointing device.

- Microsoft Excel (required for data analysis).

- VISA library
  NI-VISA3.0 or later, Agilent I/O Library M01.00 or later, or KI-VISA 2.5 or later.

- GPIB board (only when using the GPIB)
  A GPIB board made by National Instruments, Agilent Technologies, Contec Co.,LTD., or Interface Corporation.

■ Handling precautions

The application software retrieves the measurement data of the KFM2150 into the PC. To ensure that the measurement data is retrieved, disable the following operations on the PC while the test is in progress.

- Power-saver mode

- Screen saver

- Execution of memory-resident programs

In addition, do not operate other application softwares while the test is in progress.

FC Impedance Meter

● KFM2150 with firmware version 1.1X
The firmware version is shown on the display when the KFM2150 is turned on.

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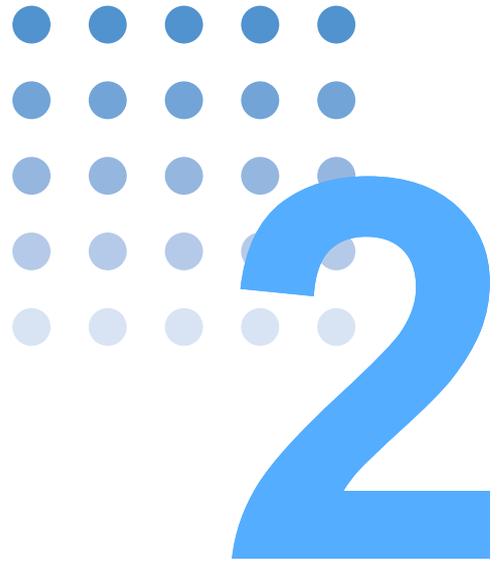
Setup

This chapter describes the procedures from unpacking to preparation before use.

2.1 Installing FCTester

1 Load the CD-ROM containing the program in the CD-ROM drive.

The installation program automatically starts.
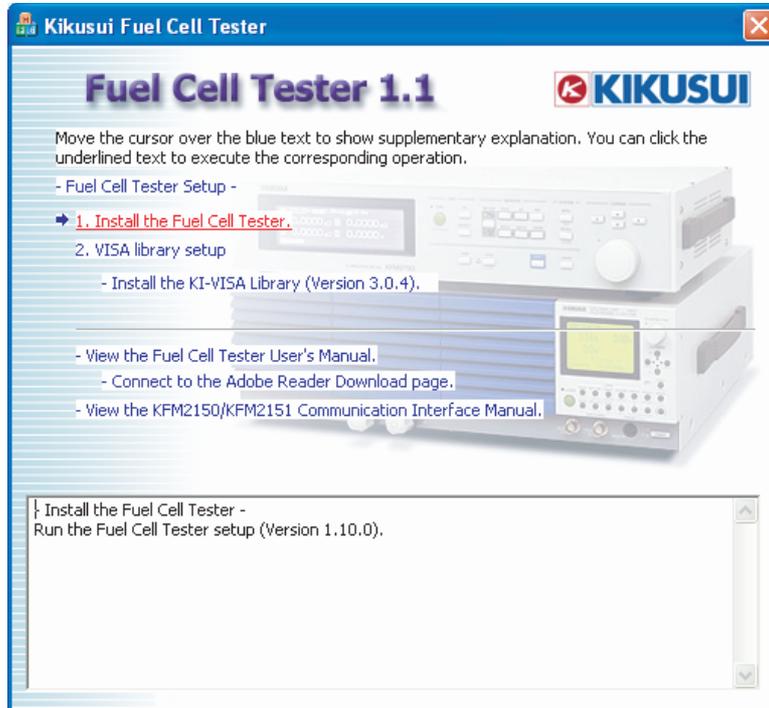
Fig.2-1   Startup window

2 Click **Install the Fuel Cell Tester**.
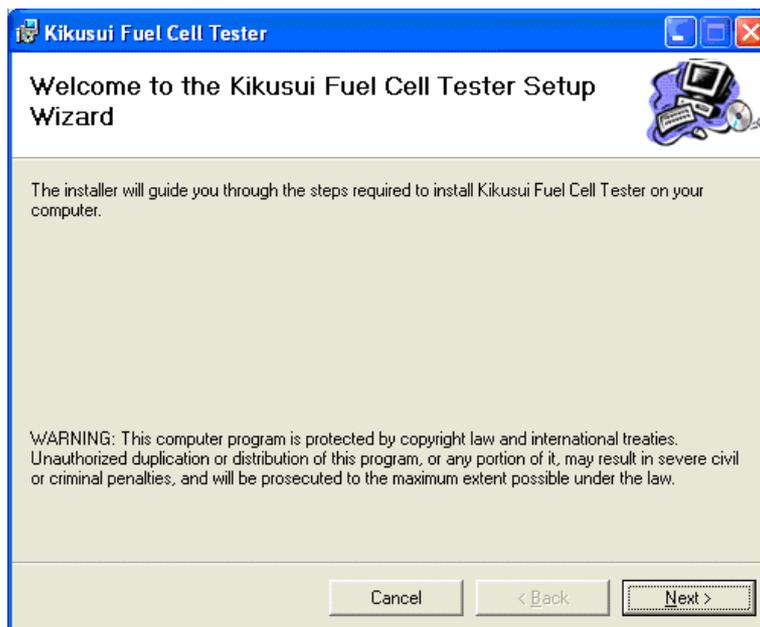
Fig.2-2   Setup startup window

3 Continue with the installation according to the instructions on the window.

When the installation is complete, the following window appears.
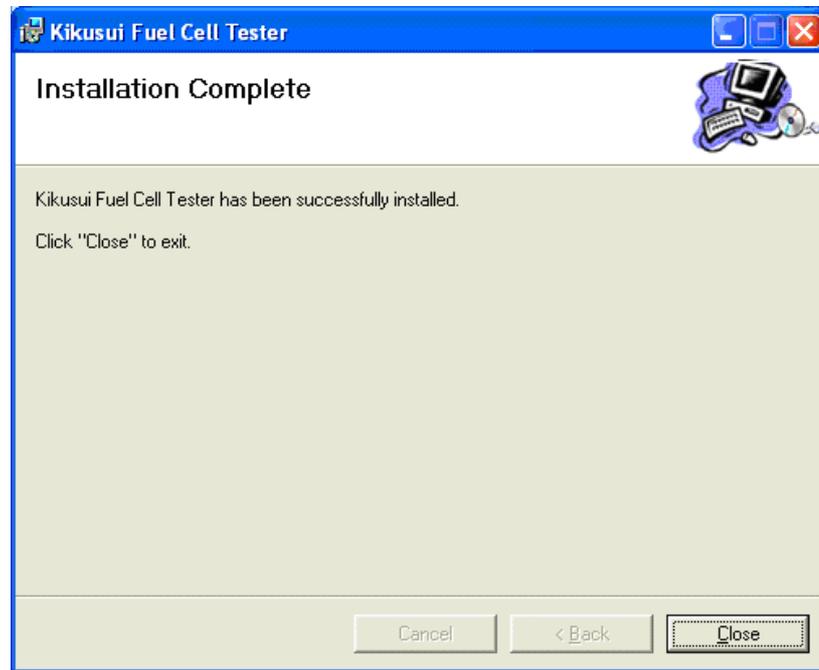
Fig.2-3　Finish window

4 Click **Close** to finish the installation.

2.2 Installing the VISA Driver

2.2.1 Preparation

You must install a VISA driver to use FCTester.

The VISA driver that is required varies depending on the I/O interface that is to be used. See Table 2-1, and select the appropriate VISA driver.

Do not install different VISA drivers on a single PC. Each VISA driver may not operate correctly.

- VISA (Virtual Instrument Software Architecture) is a specification for standard software for connecting instruments that was defined by the VXIplug&play Systems Alliance.

- A VISA driver is a software driver implemented according to the VISA Specifications.

- KI-VISA is Kikusui original VISA driver compatible with VXIplug&play VISA Specifications 2.2.

Table 2-1   Required VISA drivers

I/O interface		Required VISA driver
RS232C [1] ,[2]		KI-VISA Ver2.2.x or later NI-VISA Ver3.0 or later Agilent IO Libraries M01.00 or later
USB [1]		
GPIB [4]	By Interface Corporation[3]	KI-VISA Ver2.2.x or later
	By Contec Co., LTD.[3]	
	By National Instruments	NI-VISA Version 3.0 or later
	By Agilent Technologies	Agilent IO Libraries M01.00 or later

[1]   Any VISA driver will work when using the RS232C or USB. However, be sure to check the licensing information of the respective VISA driver.

[2]   For the RS232C, communication ports that come standard with the PC and virtual serial communication ports using USB-to-RS232C adapters are supported. However, virtual communication ports using adapters or the like may not operate properly depending on the device driver that is provided.

[3]   KI-VISA supports the following GPIB models.

Manufacturer	Model name	Notes
Contec Co., Ltd.	GP-IB(PCI)L, GP-IB(PM), GP-IB(PCI)F, and GP-IB(CB)F (API-GPIB Driver Version 4.01 or later recommended)	When using a GPIB board by Contec, use the normal API-GPIB driver, not the API-GPLV driver (compatible with LabVIEW and NI-488.2M API).
Interface Corporation	PCI-4301 LabVIEW version (GPC-4301N Driver Version 1.21 or later recommended)	When using a GPIB board by Interface, use the GPC-4301N driver (compatible with LabVIEW and NI-488.2M API), not the normal GPC-4301 driver.

*4   If you are using the GPIB, you must use the correct VISA driver. Otherwise, the GPIB will not work.

Table 2-2   Obtaining the VISA driver

VISA driver	How to obtain the driver
KI-VISA	CD-ROM for this product or KIKUSUI Website.
NI-VISA	CD-ROM that comes with the GPIB or National Instruments Website.
Agilent IO Libraries	CD-ROM that comes with the GPIB or Agilent Technologies Website.

2.2.2   Installing KI-VISA

If you are going to use KI-VISA, install it using the setup program (kivisa_x_x_x.exe) on the CD-ROM. ("x" varies depending on the KI-VISA version.) For a description of the installation of other VISA drivers, see the documentation of the respective driver.

1   Load the CD-ROM containing the program in the CD-ROM drive.

The installation program automatically starts. The window shown in Fig.2-1 opens.

If KI-VISA is already installed, **Install the KI-VISA library (Version x.x.x)** is unavailable. Because no installation is necessary, close the window. If you move the cursor over **VISA library setup**, an explanation appears at the bottom of the dialog box.

If KI-VISA is not installed, **Install the KI-VISA library (Version x.x.x)** is available. Proceed to the next step.

2   Click **Install the KI-VISA Library (Version x.x.x)**.

The installation startup window appears.
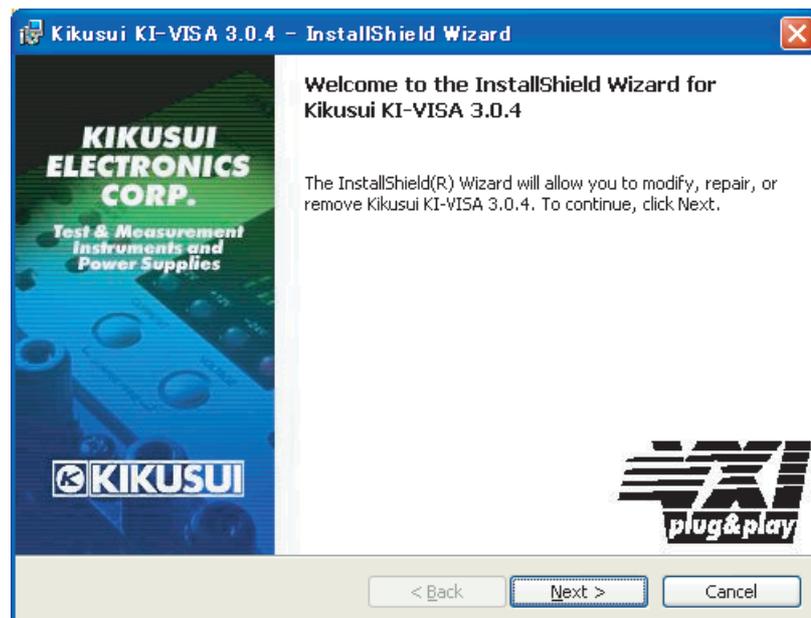
Fig.2-4   Installation startup window

3 Click **Next**.

The Program Maintenance window appears.
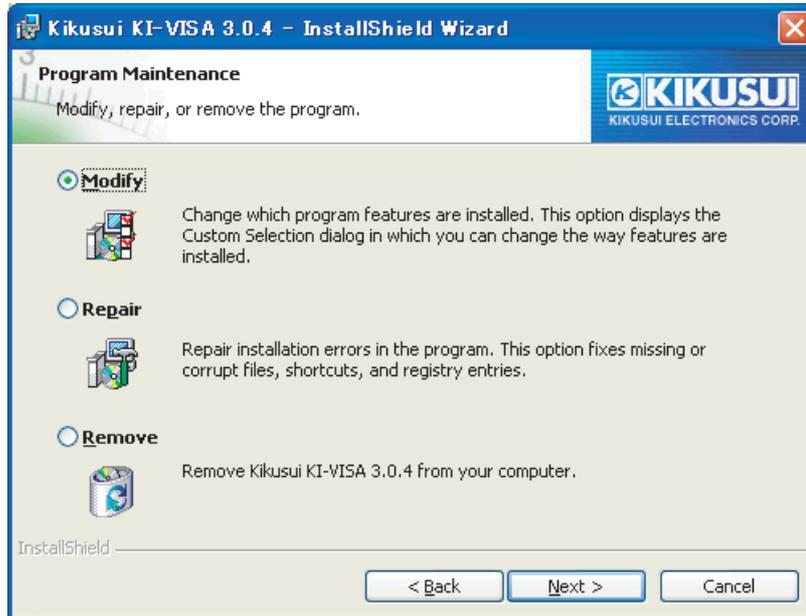
Fig.2-5　Program Maintenance window

4 Select the **Modify**.

5 Click **Next**.

The Custom Setup window appears.
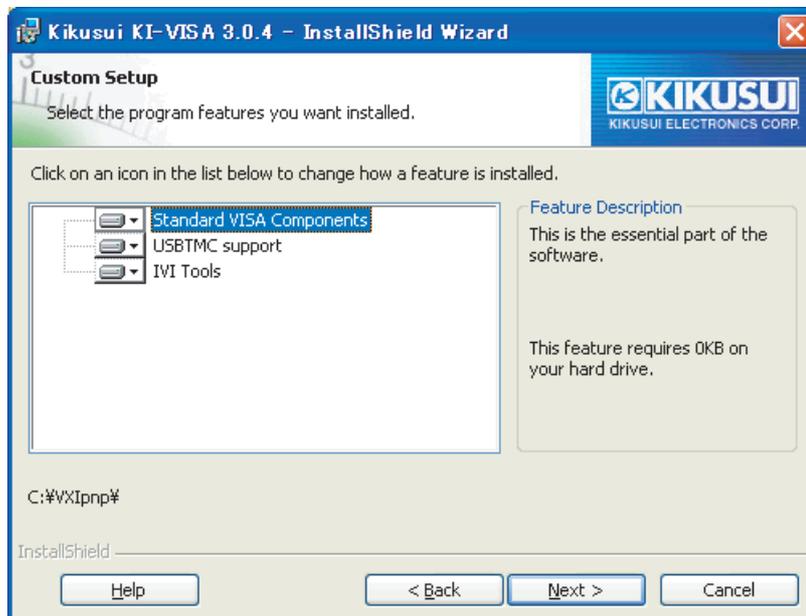
Fig.2-6　Custom Setup window

6 Click the programs you need.

7 Click **Next**.

The installation start window appears.
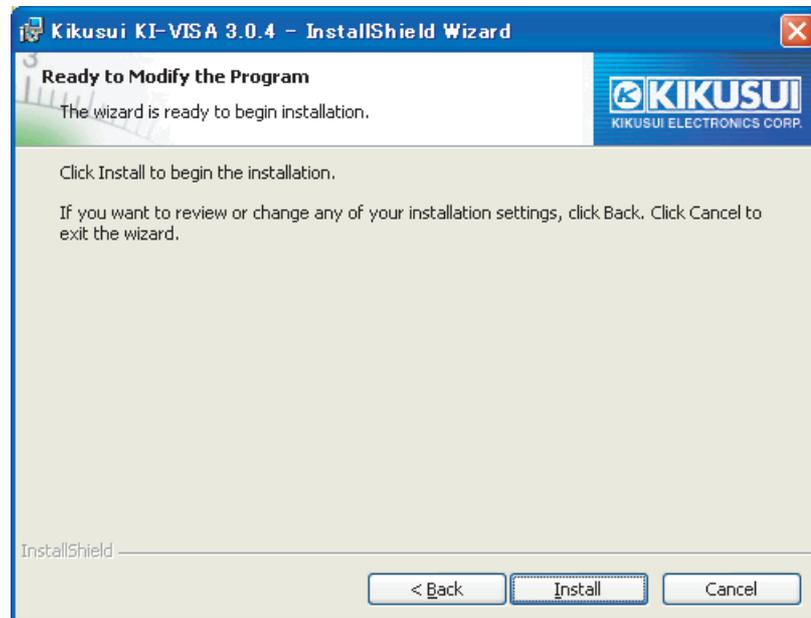
Fig.2-7 Installation start window

8 Click **Install**.

If the program already exists, the dialog box opens.
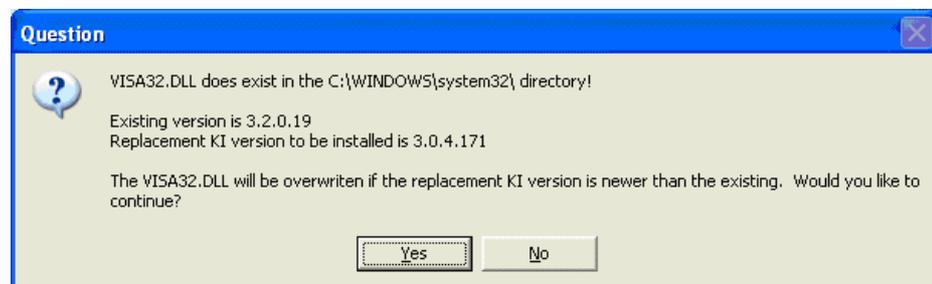
Fig.2-8 Dialog box that opens when the program exists

9 To overwrite the program, click **Yes**. Otherwise, click **No**.

When the installation is complete, the following window appears.
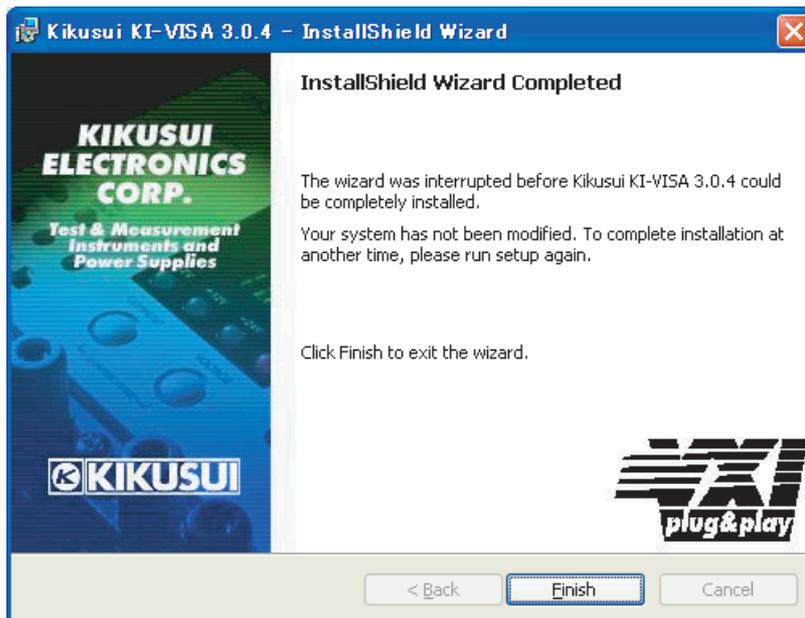
Fig.2-9   Finish window

10 Click **Finish** to finish the installation.
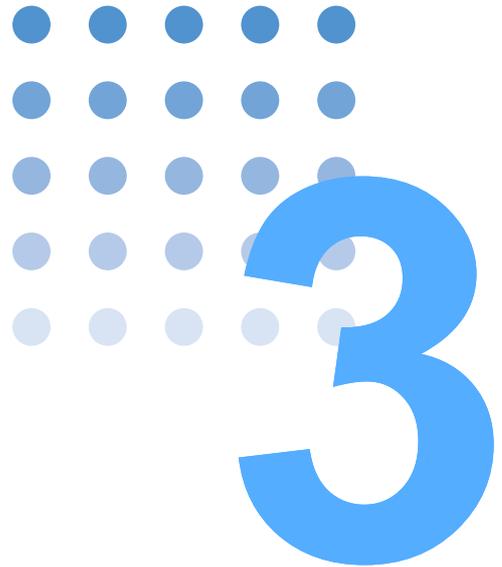
System Configuration

This chapter describes the FCTester Configuration Tool (system configuration program).

3.1   About the FCTester Configuration Tool

The FCTester Configuration Tool (hereafter referred to as the Configuration Tool) is a program used to configure the FC impedance measurement system. The program is used only when configuring the system for the first time or when you change the system configuration.

When the Configuration Tool is run, connection to each measuring instrument is checked when the system is being configured. Connection between the PC and the instrument as well as the installation of the VISA library (also the GPIB driver if you are using the GPIB) must be completed before you start the Configuration Tool.

The Configuration Tool cannot be used while the FCTester Condition Editor or the FCTester Executive program is running.

■ Items that are set using the Configuration Tool

- Impedance meter selection.

- Impedance meter and VISA resource selection.

- Scanner option selection.

- Scanner option and VISA resource selection.

- Scanner channel configuration.

■ Connecting the KFM2150 Impedance Meter to the KFM2151 Scanner

The KFM2150 is equipped with two VOLTAGE SENSING input terminals on the rear panel. The voltage sensing terminal is switched depending on wether the scanner option is used or not.

- When using the scanner option, the voltage sensing terminal is fixed to VOLTAGE SENSING 2 on the FCTester application software. Connect the VOLTAGE SENSING 2 terminal to the OUT terminal of the KFM2151 Scanner. Impedance cannot be measured if connected to the VOLTAGE SENSING 1 terminal.

- When not using the scanner option, the voltage sensing terminal is fixed to VOLTAGE SENSING 1. Impedance cannot be measured if connected to the VOLTAGE SENSING 2 terminal.

3.2 Starting the Configuration Tool

1 On the taskbar, click the Start button, and then select **Programs** > **kikusui Fuel Cell Tester 1.1** > **Configuration Tool**.

The Configuration Tool starts.
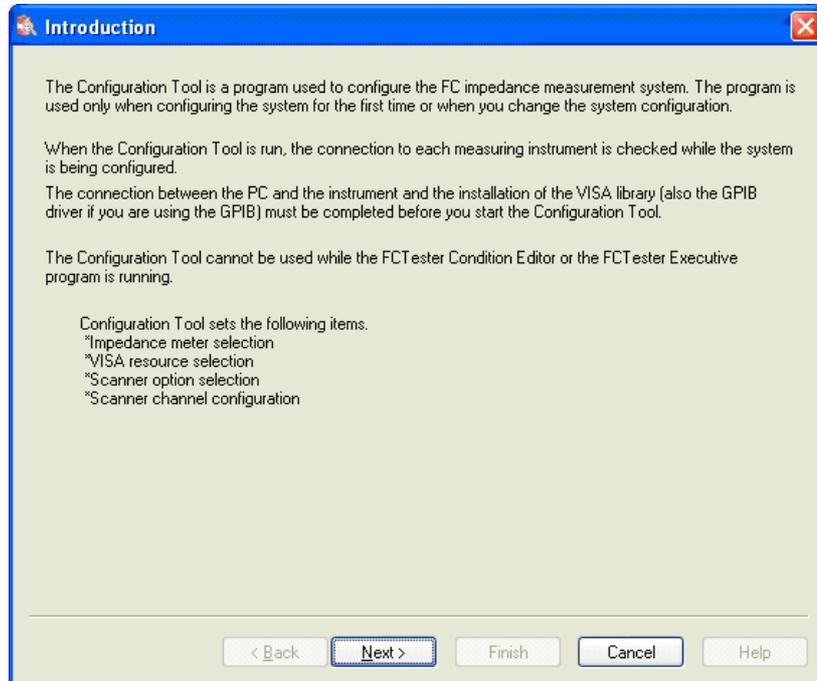
Fig.3-1   Startup window

2 Click **Next**.
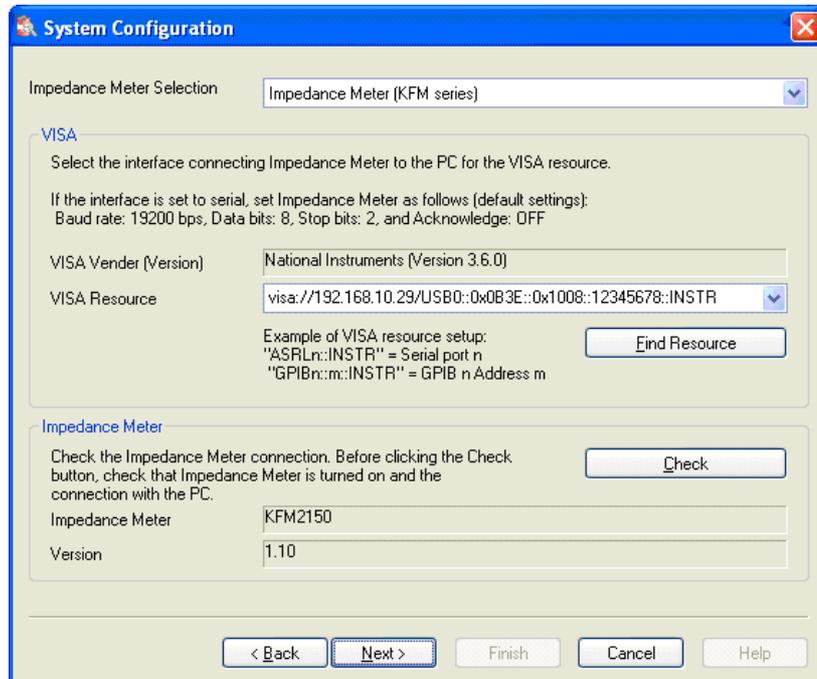
Fig.3-2   System Configuration

On the System Configuration window, select the impedance meter, select the VISA resource, and check the connection to the impedance meter.

■ Selecting the impedance meter

Select an impedance meter (KFM Series).

■ Selecting the VISA resource

Select or type the VISA resource.

The selectable VISA resources are shown. Click **Find Resource** to search the VISA resource again.

Table 3-1   VISA resource expression example

Type	Syntax	VISA resource example	Description
GPIB	GPIB Board :: PrimaryAddress :: INSTR	GPIB0 :: 3 :: INSTR	Measuring instrument connected to GPIB0 with a primary address set to 3
Serial	ASRL Board :: INSTR	ASRL1 :: INSTR	Measuring instrument connected to serial port COM1
USB	USB0 :: VendorID :: ProdutID :: SerialNumber :: INSTR	USB0 :: 0x0B3E :: 0x1008 :: ABC12345 :: INSTR	USBTMC measuring instrument with vendor ID: 2878 (Kikusui), product:[1] ID1008 (KFM2150), and serial number: ABC12345.

*1.   The PLZ-4W Series is ID1004.

■ Checking the connection to the impedance meter

After selecting the impedance meter and VISA resource, click **Check** to check the connection.

If the connection is detected correctly, the impedance meter name and version appear, and the **Next** button becomes available.

If the connection is not correct, a dialog box shown in Fig.3-3 opens. Check that the POWER switch of impedance meter (KFM2150) is turned on and that the interface connection is correct.

After checking and correcting the connection, click **OK** to proceed to the next step.
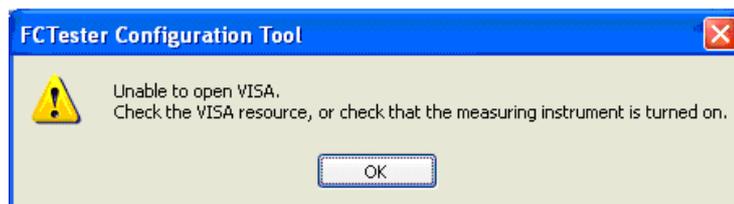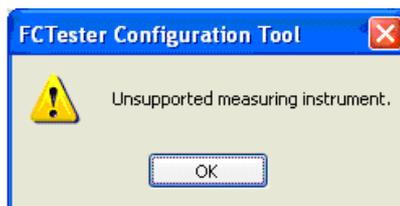
Fig.3-3   Incorrect connection

■ **When not selecting the scanner option**

To select the scanner option, see ⅄ When selecting the scanner option Ŧ on page 3-6.

3 Click **Next**.

Clear the **Use the scanner option** check box.
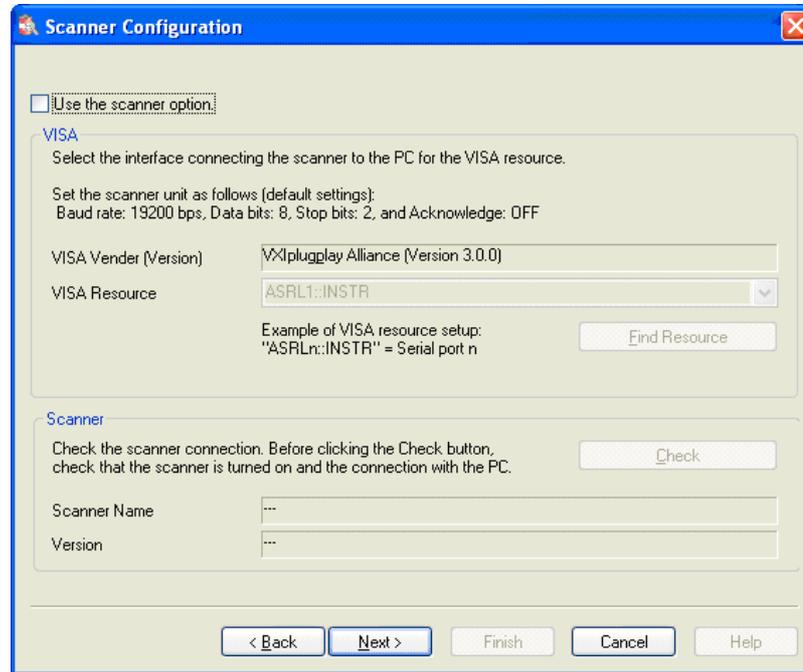
Fig.3-4   Scanner Configuration

4 Click **Next**.
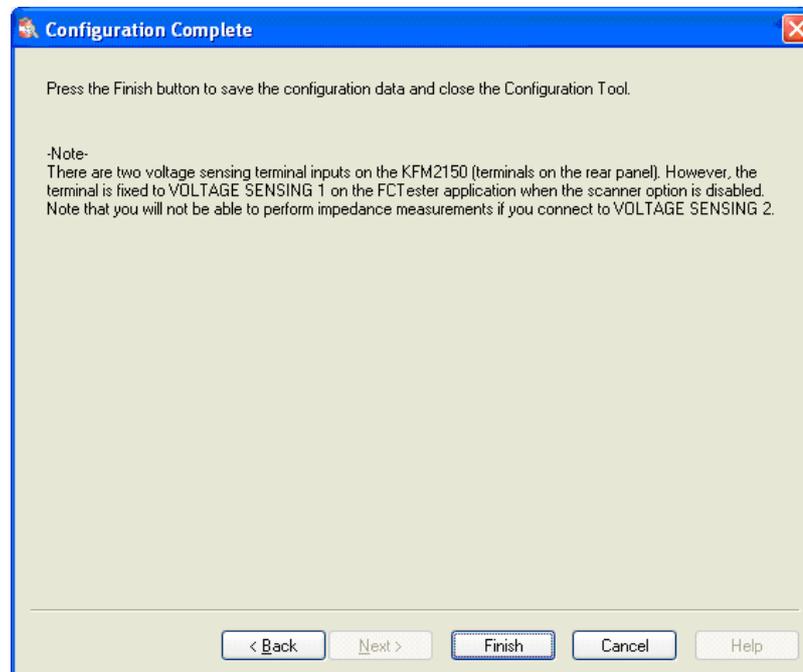
Fig.3-5   Configuration Complete

5 Click **Finish**.

The configuration data is stored, and the Configuration Tool closes.

■ **When selecting the scanner option**

3 Click **Next**.
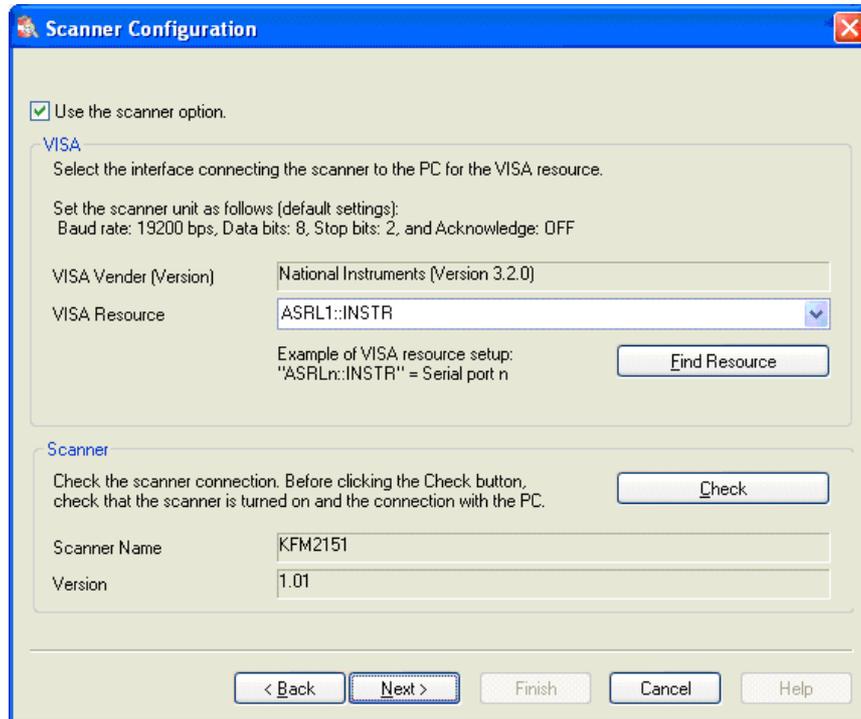
Fig.3-6   Scanner Configuration

On the Scanner Configuration window, select the scanner usage and VISA resource, and check the connection to the scanner.

■ **Scanner usage**

Select the **Use the scanner option** check box.

■ **Selecting the VISA resource**

Select or type the VISA resource.

The selectable VISA resources are shown. Click **Find Resource** to search the VISA resource again.

■ **Checking the connection to the scanner**

After selecting the scanner usage and VISA resource, click **Check** to check the connection.

If the connection is detected correctly, the scanner name and version appear, and the **Next** button becomes available.

If the connection is not correct, a dialog box shown in Fig.3-7 opens. Check that the POWER switch of scanner (KFM2151) is turned on and that the interface connection is correct.

After checking and correcting the connection, click **OK** to proceed to the next step.
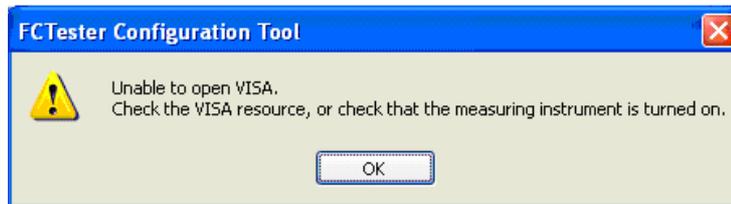
Fig.3-7   Incorrect connection

4   Click **Next**.
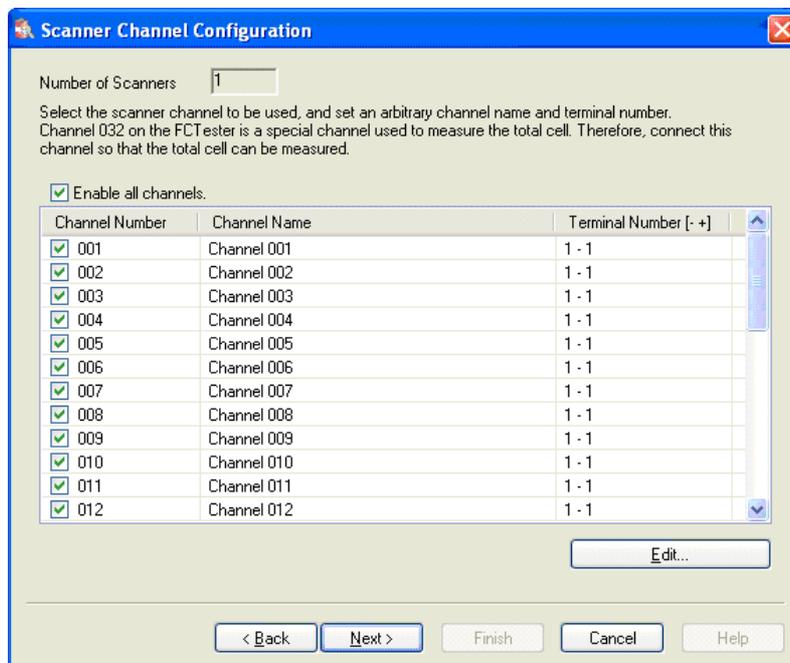
Fig.3-8   Scanner Channel Configuration

Information such as the Number of Scanners and Channel Number are displayed according to the system configuration.

If you select the **Enable all channels** check box, all the channels are enabled, and the check boxes of all channel numbers are selected.

If you clear the **Enable all channels** check box, all channels except channel 032 are disabled.

Select the check box of a given channel to enable that channel. Clear the check box to disable it.

NOTE   • As the number of channels increases in the Scanner Channel Configuration window, the time it takes to retrieve the voltage data also increases. We recommend that you select only the channels that you need.

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5   Click **Edit**.
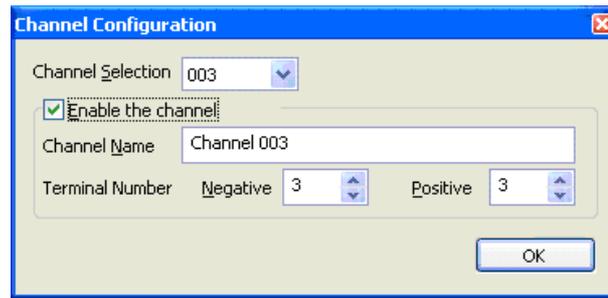
Fig.3-9   Channel Configuration

■ **Selecting the channel**

Select the channel number.

■ **Enabling the channel**

To enable the selected channel, select the **Enable the channel** check box. Otherwise, clear the check box.

If you enabled the channel, specify the channel name (up to 64 characters) and the terminal number.

Configure all other necessary channels in the same manner.

> Channel 032 on the FCTester is a special channel used to measure the stack. Connect this channel so that the stack is measured. This channel cannot be disabled.

Fig.3-10   Channel 032 cannot be disabled.

6   Click **OK**.

The Scanner Channel Configuration window (Fig.3-8) appears.

7   Click **Next** and then click **Finish**.

The configuration data is stored, and the Configuration Tool closes.

Creating Test Conditions

This chapter describes the FCTester Condition Editor (test condition editing program).

4.1 About the FCTester Condition Editor

The FCTester Condition Editor (hereafter referred to as the Condition Editor) is a program used to edit test conditions.

You can combine up to 15 sequences of test modes in one cycle of a test condition file.

The Condition Editor allows you to set the following items.

• Fuel cell information

• Protection

• Cycle

• Startup sequence

• Shutdown sequence

• Sequence 1 to 15 (select from nine test modes for each sequence)

• Test mode (9 modes)
   I-V measurement
   I-V + AC impedance measurement
   I-V + Cole-Cole plot measurement
   V-I measurement
   Cole-Cole plot measurement
   AC impedance measurement
   Current interrupt measurement
   Constant current test
   Constant voltage test

4.2   Starting the Condition Editor

1   On the taskbar, click the Start button, and then select **Programs** > **kikusui Fuel Cell Tester 1.1** > **FCTester Condition Editor**.

The Condition Editor starts.

Test Conditions
Item Pane

Test Conditions
Edit Pane
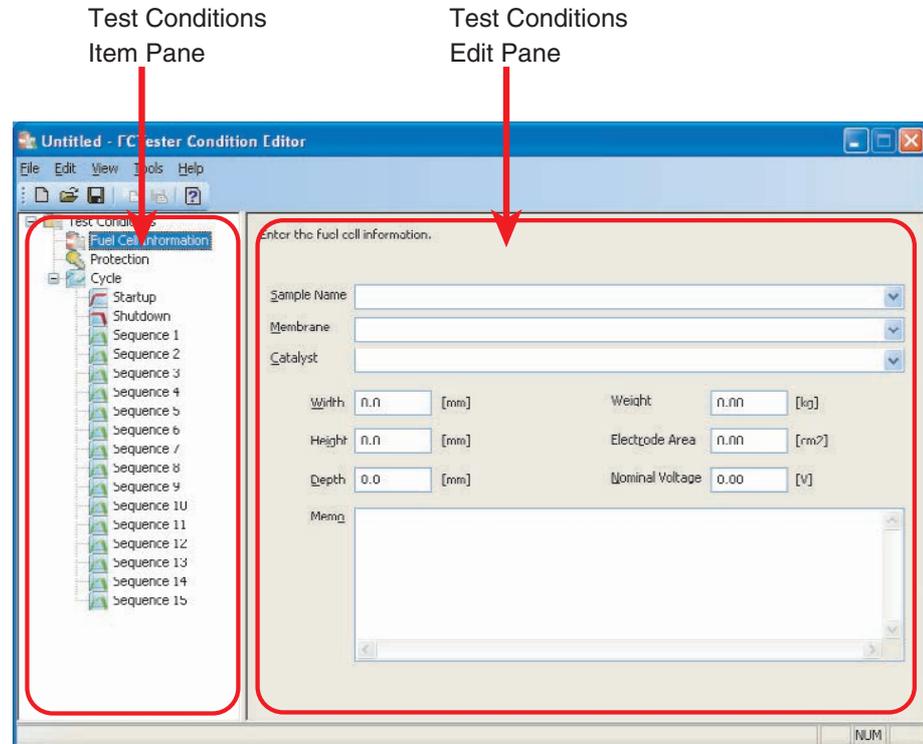
Fig.4-1   Startup window

The startup window consists of two panes.

Pane	Description
Test Conditions Item Pane	The test condition items are divided into sheets. The sheet names are shown in a tree structure. You select the sheet that you want to edit on this pane.
Test Conditions Edit Pane	Shows the contents of the sheet that is selected in the Test Condition Item Pane. You edit the condition items of each sheet on this pane. The input range of an item is shown by moving the pointer over the corresponding box.

4.3 Creating and Saving Test Conditions Files

Creating a test conditions file

■ Creating a new file

1 From the **File** menu, select **New**.

A file with the name Untitled opens. The startup window opens.
Specify the settings by referring to the subsequent sections.

■ Opening an existing file

1 From the **File** menu, select **Open**.

The Open window opens.

2 Select the file you want to open.

The extension of the test conditions file is .fcct.

Saving the test conditions file

1 From the **File** menu, select **Save**.

The test conditions file that is currently open is saved.
If you are saving the current file the first time, the Save As dialog box opens. Specify the save destination and the file name. The extension of the test conditions file is .fcct.

To save the file with another name, select **Save As**. The Save As dialog box opens. Specify the save destination and file name.

■ Setting the default file

From the **File** menu, select **Default**.

You can set the current file to be the default file when a new file is created.

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NOTE
- The test data files that the FCTester Executive generates are placed in the same location as the test conditions file. Many test data files are created in a single test. If you want to place the test conditions file on the desktop, we recommend that you create a dedicated folder on the desktop and place the file in the folder.

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4.4   Fuel Cell Information

This window is used to enter information concerning the sample (fuel cell).

1   In the Test Condition Item Pane, click **Fuel Cell Information**.
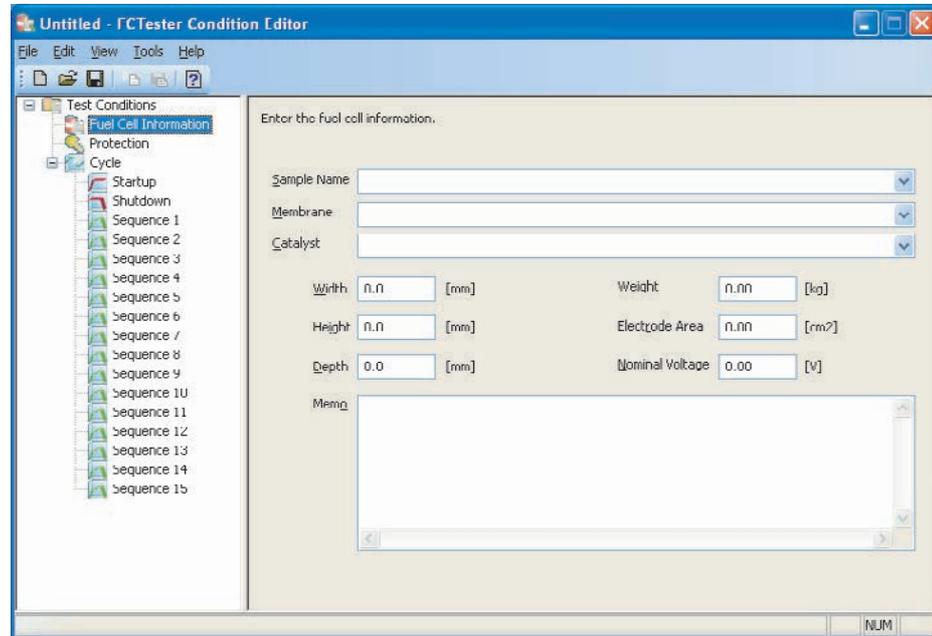
Fig.4-2   Fuel Cell Information

Item	Input range
Sample Name	Up to 64 arbitrary characters. You can enter more than 64 characters, but they are discarded. Text entered in the past are stored and displayed in the drop-down list when you click the arrow.
Membrane	
Catalyst	
Dimensions (W, H, and D)	0.0 to 10000.0 [mm]
Weight	0.00 to 1000.00 [kg]
Electrode Area	0.00 to 100000.00 [cm^2]
Nominal Voltage	-2.00 to 150.00[V]
Memo	Up to 256 arbitrary characters.

NOTE

- The electrode area is used when displaying the current on the graph scale of the FCTester Executive in current density.
- The nominal voltage is used as the maximum value when the voltage on the graph scale of FCTester Executive is fixed.

4.5   Protection

This window is used to set the protection function of the impedance meter, electronic load unit, and scanner.

1   In the Test Condition Item Pane, click **Protection**.
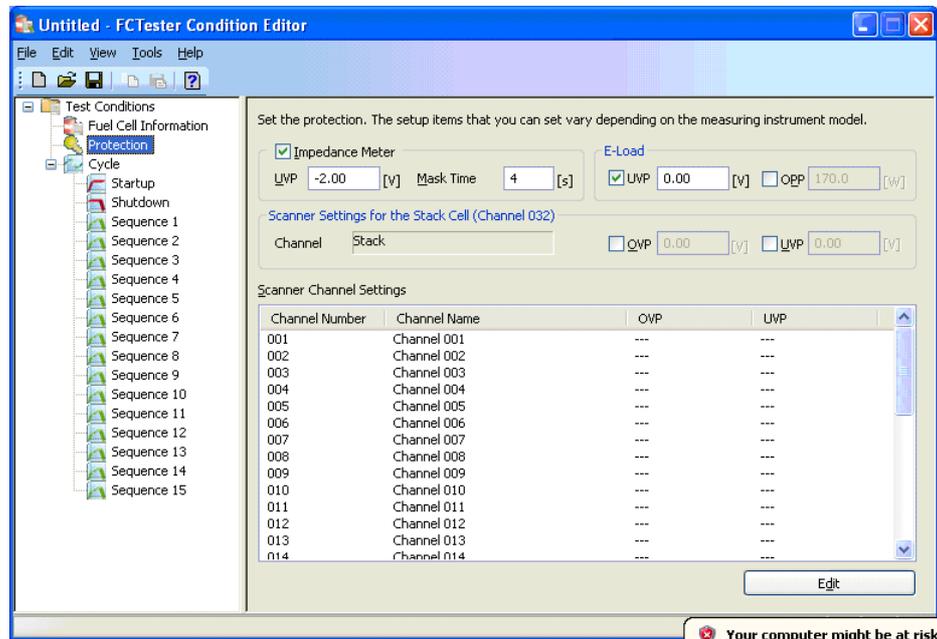
Fig.4-3   Protection

Common settings

Item		Description	Input range
Impedance meter	UVP	Select the check box to enable the undervoltage protection (UVP) function of the impedance meter.	-2.00 to 150.00 [V]
	Mask Time	Select the check box to set the time (mask time) until the undervoltage protection (UVP) of the impedance meter is to be activated.	0 to 10 [s]
E-Load	UVP	Select the check box to enable the undervoltage protection (UVP) function of the electronic load unit.	0.00 to 150.00 [V]
	OPP	Select the check box to enable the overpower protection (OPP) function of the electronic load unit.	*1
Stack channel settings (channel 032) of the scanner	OVP	Select the check box to enable the overvoltage protection (OVP) function of the scanner.	-2.00 to 200.00 [V]
	UVP	Select the check box to enable the undervoltage protection (UVP) function of the scanner.	-2.00 to 200.00 [V]

*1.   Depends on the capacity of the electronic load unit that is being used.

Settings of each scanner channel

You must select the scanner option on the Configuration Tool in advance to use the channel settings of the scanner.

1 Click **Edit**.
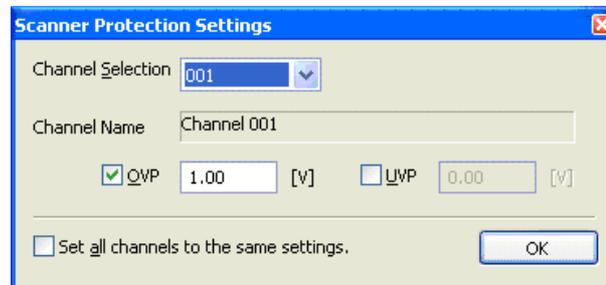
Fig.4-4   Scanner Protection Settings

Select the scanner channel on which you want to set the protection.

The settings are displayed in **Scanner Channel Settings** in the Test Condition Edit Pane.

Item	Description	Input range
Channel selection	Select the channel you want to set.	Depends on the number of scanners[1]
OVP	Select the check box to enable the overvoltage protection (OVP) function of the scanner.	-2.00 to 200.00 [V]
UVP	Select the check box to enable the undervoltage protection (UVP) function of the scanner.	-2.00 to 200.00 [V]
Set all channels to the same settings.	Select the check box to set the OVP and UVP values to the same values on all channels.	Same as OVP and UVP

[1].   001 to 031 for 1 unit, 101 to 132 for 2 units, 201 to 232 for 3 units, 301 to 332 for 4 units, and 401 to 432 for 5 units.

4.6   Cycle

A cycle consists of multiple sequences (up to 15) that can be tested repetitively (Fig.4-5). You can set one test mode in a sequence and combine the sequences to perform various tests in a cycle. Startup and shutdown sequences, which define the startup and shutdown operations of the fuel cell, can be executed at the start and end of the cycle test.
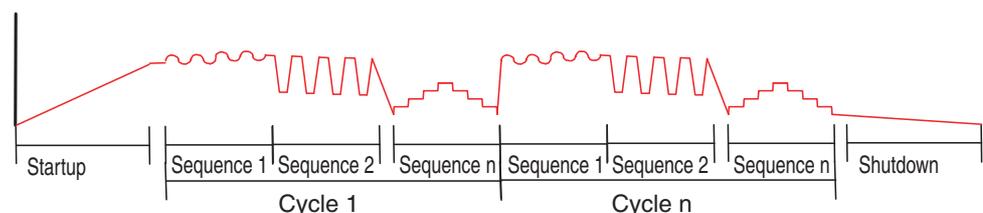
Fig.4-5   Concept of cycles

■ **Turning the load on/off (turning the load current on/off)**

If the current range or voltage range between two adjacent sequence sheets is the same, the cycle continues with the load turned on. If not, the load is turned off instantaneously at the start of the sequence, and the current range or voltage range is switched.

■ **OCV (Open Circuit Voltage)**

If you are turning the load off to measure the OCV (Open Circuit Voltage) before a sequence, the load is turned off once regardless of whether the voltage range or current range is the same. You can set the load off period.

■ **Setting the recording conditions**

You can set the recording conditions of the voltage and current data for each sequence. You can select the points to be recorded in the recording conditions to reduce the number of recorded data values.

You can select multiple items in each recording condition. If you clear all the recording condition check boxes, voltage and current are not recorded in the test data file.

All of the recording data of the impedance meter are recorded regardless of the conditions.

1 In the Test Condition Item Pane, click **Cycle**.
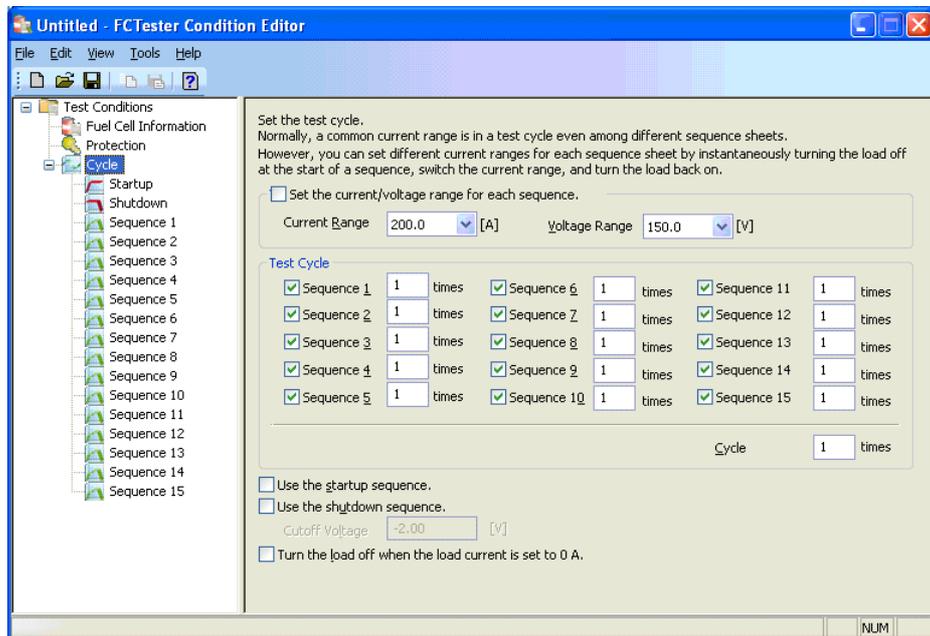
Fig.4-6   Cycle

Item	Description	Input range
Set the current/voltage range for each sequence.	If you select the check box, the Voltage Range and Current Range of the electronic load unit become unavailable. The voltage and current settings are enabled in each sequence. If you select the check box, you can set the current and voltage ranges of the electronic load unit. The ranges are set to the same ranges in all sequences. Settings in each sequence is not allowed (the Current Range and Voltage Range boxes become unavailable).	(No relevant values)
Current Range	The current range of the electronic load unit that is set by clearing the check box. The range is set to the specified range in all sequences.	*1
Voltage Range	The voltage range of the electronic load unit that is set by clearing the check box. The range is set to the specified range in all sequences.	15.0 [V] or 150.0 [V]
Test Cycle Sequence 1 to 15	Select the check box to enable that sequence. Specify the number of times to repeat each sequence.	1 to 10
Cycle	Specify the number of times to repeat the cycle.	1 to 100
Use the startup sequence.	Select the check box to execute the startup sequence before executing the first cycle. If the startup sequence is enabled, the load is automatically turned on even if the load is not on before starting the test. If the startup sequence is disabled, you must manually turn the load on before starting the test. [*2]	(No relevant values)
Use the shutdown sequence.	Select the check box to execute the shutdown sequence after the last cycle is executed. If the shutdown sequence is disabled, you must manually turn the load of after the test. [*3]	(No relevant values)
Cutoff Voltage	This item is enabled if you select the Use the shutdown sequence check box. If the voltage falls below the Cutoff voltage during a test cycle, the present sequence is terminated, and transition is made to the shutdown sequence.	-2.00 to 150.00 [V]
Turn the load off when the load current is set to 0 A.	Select the check box to turn the load off when the load current is set to 0 A. This setting is applied only to the I-V measurement, I-V + current impedance measurement, and I-V + Cole-Cole plot measurement.	(No relevant values)

*1. Depends on the capacity of the electronic load unit that is being used.
*2. For the operating procedure, see section 5.3.2, ⅄ Not Using the Startup Sequence."
*3. For the operating procedure, see section 5.3.7, ⅄ Test Completion."

4.7 Startup

1 In the Test Condition Item Pane, click **Startup**.

The startup sequence is a sequence for the fuel cell that is executed before starting the test cycle.
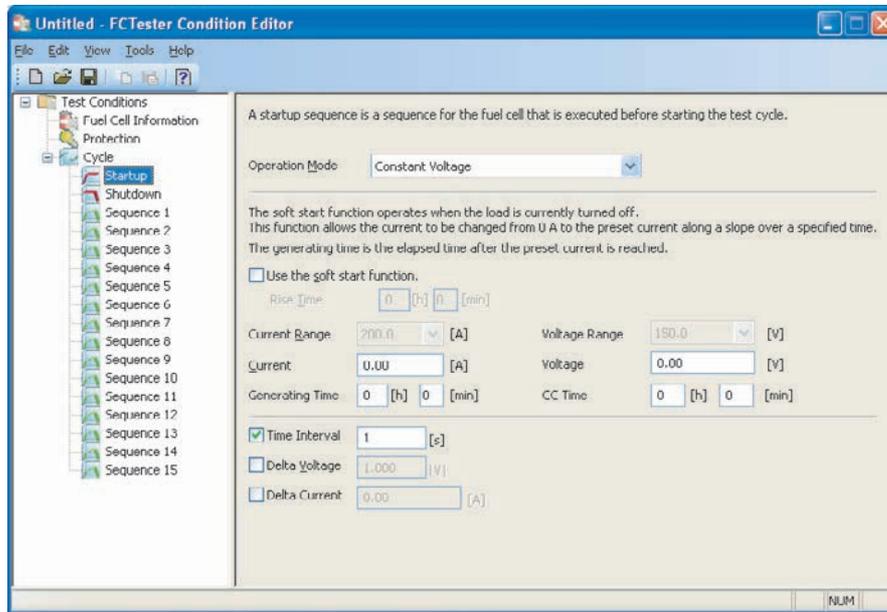
Fig.4-7   Startup
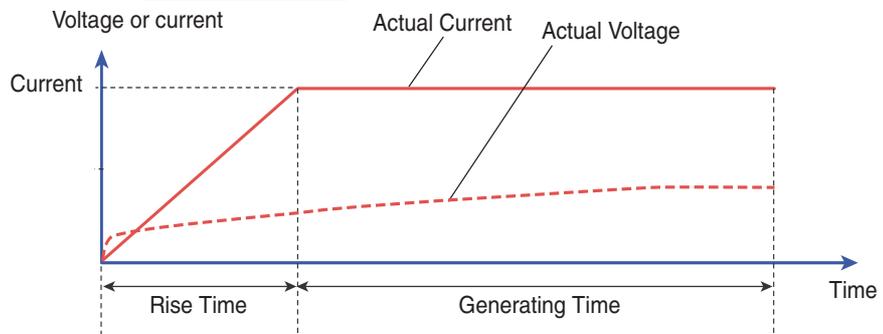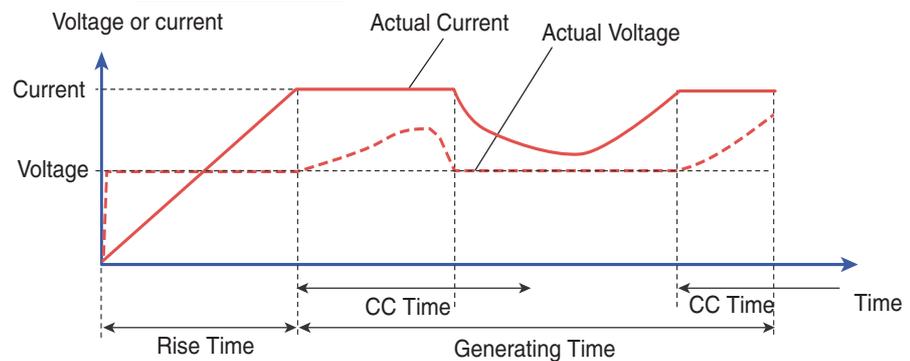
Fig.4-8   Conceptual diagram of startup

Item	Description	Input range
Operation Mode	Specifies the operation mode of the startup sequence.	Constant current or constant voltage
Use the soft start function.	Select the check box to enable the soft start function. The current increases from the present value to the load current along a slope over the specified rise time. If this function is enabled, the generating time is the elapsed time since the load current is reached.	(No relevant values)
Rise Time	The load current is changed step-wise at 1 second interval. The current rises from 0 A to the load current over the specified time.	0 to 2 [h] 0 to 59 [min]
Current Range	Sets the current range of the electronic load unit.	*1
Current	Sets the load current.	*1
Generating Time	Sets the generating time of the startup sequence (the time after the preset current is reached).	0 to 8 [h] 0 to 59 [min]
Voltage Range	Sets the voltage range of the voltage for switching to constant voltage mode. This item is unavailable if the operation mode is constant current.	15.0 [V] or 150.0 [V]
Voltage	Sets voltage for switching to constant voltage mode. This item is unavailable if the operation mode is constant current.	0 to 157.5 [V] or 0 to 15.75 [V]
CC Time	This item is unavailable if the operation mode is constant current. The CC Time sets the time from the point when the load current is reached. If the current falls below the load current within the specified time, the specified time is reset.	0 to 8 [h] 0 to 59 [min]
Time Interval	Sets the time interval of measurements.	1 to 3600 [s]
Delta Voltage	Continues the measurement in the period where the voltage change is greater than or equal to the specified delta voltage when the operation mode is constant current.	0.001 to 1.000 [V]
Delta Current	Continues the measurement in the period where the current change is greater than or equal to the specified delta current when the operation mode is constant current.	The minimum resolution of the current range to 10 % of the current range[*1]

*1. Depends on the capacity of the electronic load unit that is being used.

4.8   Shutdown

1 In the Test Condition Item Pane, click **Shutdown**.

The shutdown sequence is a sequence for the fuel cell that is executed after the end the test cycle.
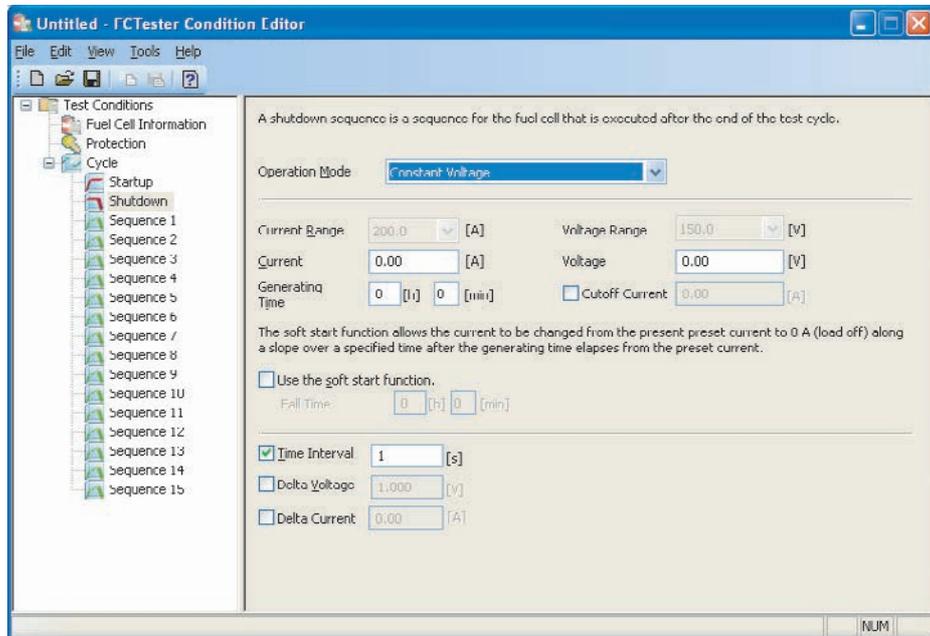
Fig.4-9   Shutdown
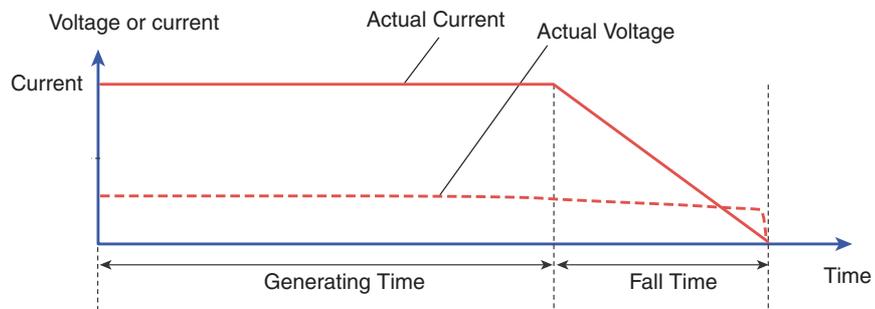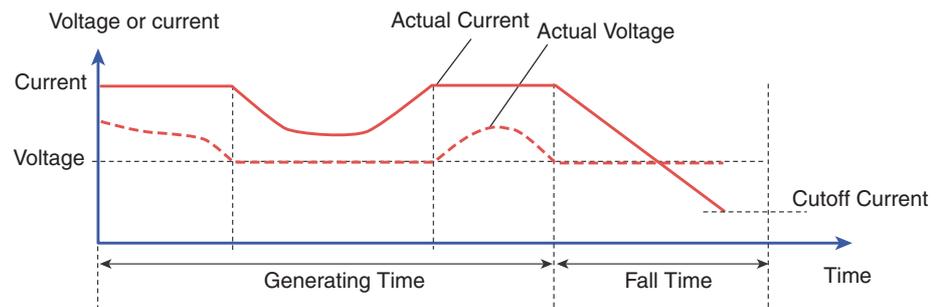
Fig.4-10   Conceptual diagram of shutdown

Item	Description	Input range
Operation Mode	Specifies the operation mode of the shutdown sequence.	Constant current or constant voltage
Current Range	Sets the current range of the electronic load unit.	[1]
Current	Sets the load current.	[1]
Generating Time	Sets the generating time of the shutdown sequence (the time after the preset current is reached).	0 to 8 [h] 0 to 59 [min]
Voltage Range	Sets the voltage range of the voltage for switching to constant voltage mode.	15.0 [V] or 150.0 [V]
Voltage	Sets voltage for switching to constant voltage mode.	0 to 157.5 [V] or 0 to 15.75 [V]
Cutoff Current	If the current falls below the preset value when the operation mode is constant voltage, the shutdown sequence is terminated, and the load is turned off.	
Use the soft start function.	Select the check box to enable the soft start function. The current decreases from the present value to 0 A along a slope over the specified fall time. If this function is enabled, the generating time is the time that passes after the load current is reached.	(No relevant values)
Fall Time	The load current is changed step-wise at 1 second interval. The current falls from the load current to 0 A over the specified time.	0 to 2 [h] 0 to 59 [min]
Time Interval	Sets the time interval of measurements.	1 to 3600 [s]
Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000 [V]
Delta Current	The data before the load current value is changed is recorded.	The minimum resolution of the current range to 10 % of the current range[1]

[1]. Depends on the capacity of the electronic load unit that is being used.

4.9   Sequence Sheets 1 to 15

Sequence sheets are used to define each sequence that make up the cycle. The Test Conditions Pane has the Measurement and Scanner tabs. The scanner tab only corresponds to test modes in which impedance measurements are performed.

Measurement tab

The following test modes are available. The items that you can set vary depending on the test mode.

- I-V measurement
- I-V + AC impedance measurement
- I-V + Cole-Cole plot measurement
- V-I measurement
- Cole-Cole plot measurement
- AC impedance measurement
- Current interrupt measurement
- Constant current test
- Constant voltage test
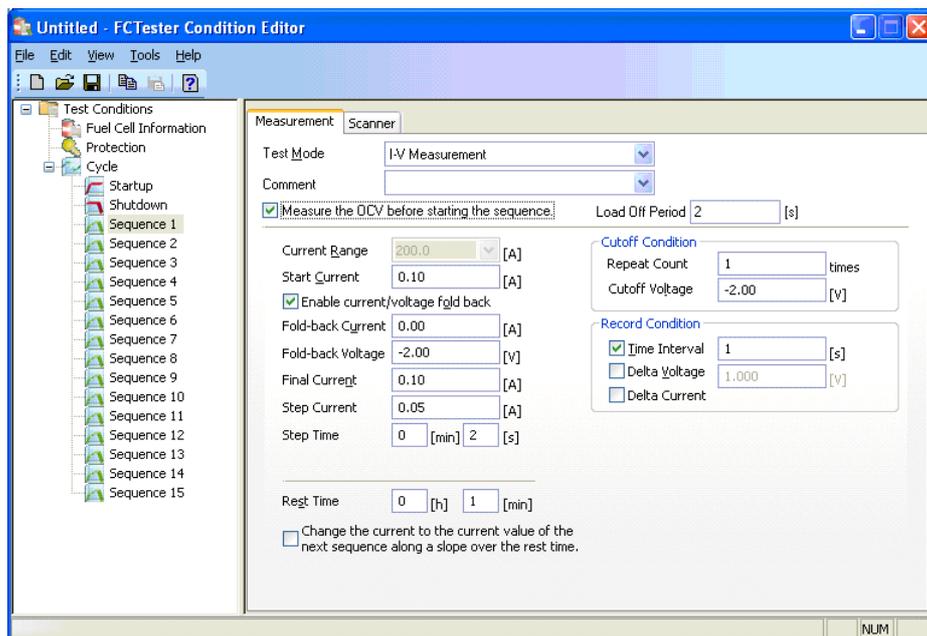
Fig.4-11   Measurement tab

You can set the recording conditions of the voltage and current data for each sequence. You can select the points to be recorded in the recording conditions to reduce the number of recorded data values.

You can select multiple items in each recording condition. If you clear all the recording condition check boxes, voltage and current are not recorded in the test data file.

All of the recording data of the impedance meter are recorded regardless of the conditions.

Scanner tab

Scanning is supported only for the following test modes that perform impedance measurement.

- I-V + AC impedance measurement
- I-V + Cole-Cole plot measurement
- Cole-Cole plot measurement
- AC impedance measurement
- Current interrupt measurement
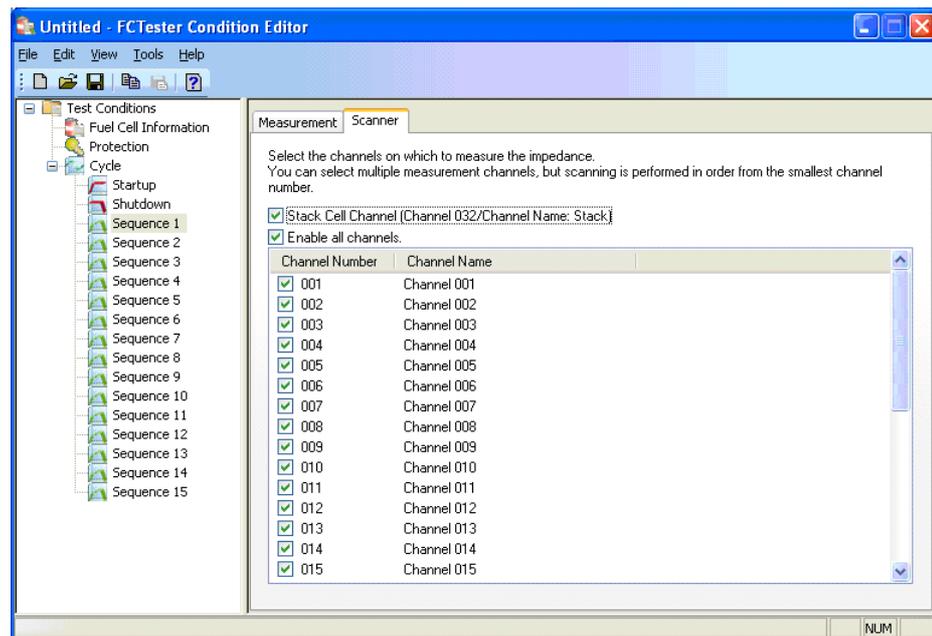
Fig.4-12   Scanner tab

If you select one of the test modes above, you will be able to select channels on the **Scanner** tab.

Select the check box of a given channel to enable the channel as a channel on which impedance measurement will be performed. Clear the check box to disable the channel.

You can arbitrarily select the channels to be measured, but scanning is performed in order from the smallest channel number.

- If you select the **Stack Cell Channel (Channel 032/Channel Name: Stack)** check box, channel 032 is enabled. If you select the **Enable all channels** check box, channel 032 is automatically enabled.

- If you select the **Enable all channels** check box, all the channels are enabled, and the check boxes of all channel numbers are selected. If you clear the check box, all channels are disabled.

NOTE
- You must select the scanner option on the Configuration Tool to use the **Scanner** tab.
- The voltage data of a channel that is enabled using the Configuration Tool is enabled even if the channel is not selected in the Scanner tab of Fig.4-12.

4.9.1　I-V Measurement

This test mode varies the load current in steps and measures the voltage.

1　In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2　In the **Test Mode** box, select **I-V measurement**.
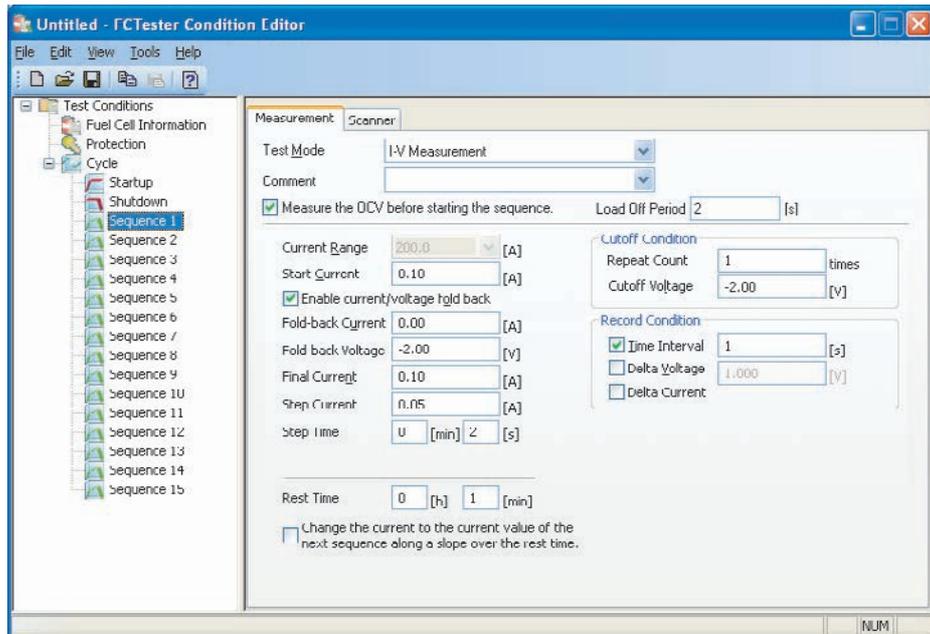
Fig.4-13　I-V measurement
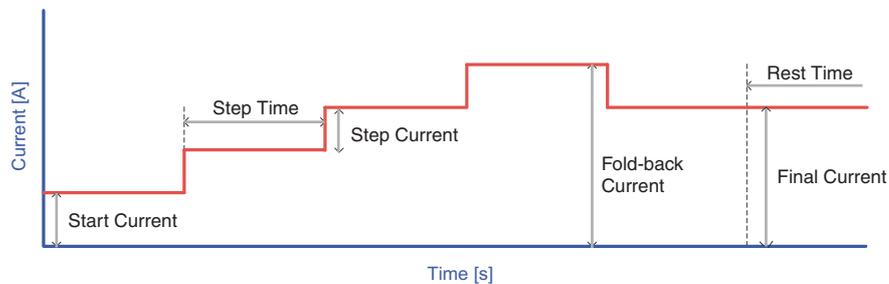
Fig.4-14　Conceptual diagram of I-V measurement

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Start Current		Sets the current at which the load current sweep is started.	*1
Enable current/voltage fold back		Select the check box to fold back the current sweep.	(No relevant values)
Fold-back Current		Sets the current at which the current sweep is folded back.	*1
Fold-back Voltage		Sets the voltage at which the current sweep is folded back. If the cell voltage is less than or equal to the fold-back voltage when the current sweep is increasing, the current sweep is folded back.	0 to 157.5 [V] or 0 to 15.75 [V]
Final Current		Sets the current at which the load current sweep is stopped.	*1
Step Current		Sets the step current for sweeping the load current in steps.	*1
Step Time		Sets the time for each step.	0 to 59 [min] 0 to 59 [s]
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Cutoff Condition	Repeat Count	Sets the number of times to repeat the I-V test.	1 to 999 times
	Cutoff Voltage	The sequence is terminated if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]
	Delta Current	The data before the load current value is changed is recorded.	(No relevant values)

*1.   Depends on the capacity of the electronic load unit that is being used.

4.9.2 I-V + AC Impedance Measurement

This test mode varies the load current in steps and measures the AC impedance after the step time elapses.

1 In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2 In the **Test Mode** box, select **I-V + AC Impedance Measurement**.
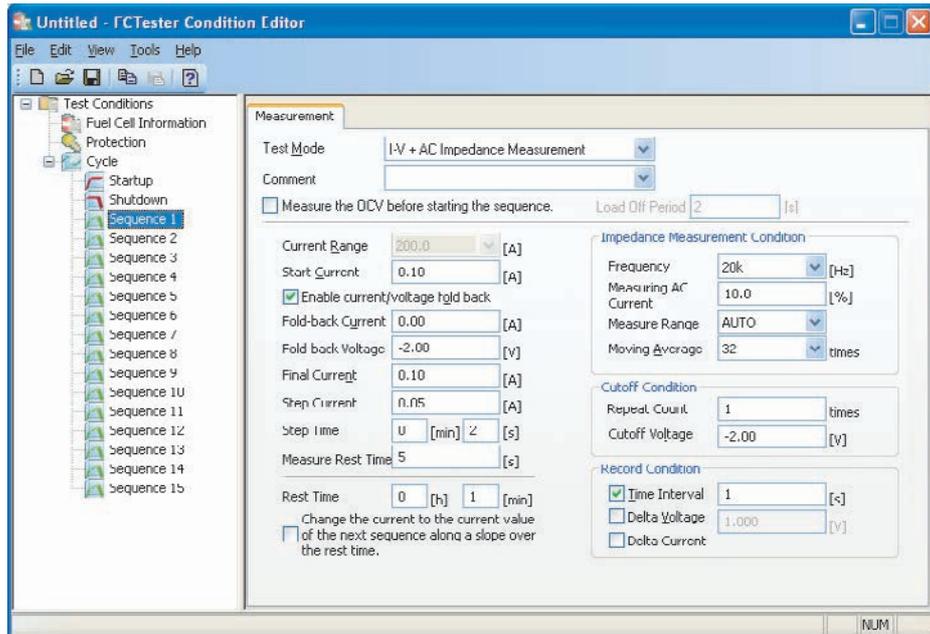
Fig.4-15 I-V + AC impedance measurement
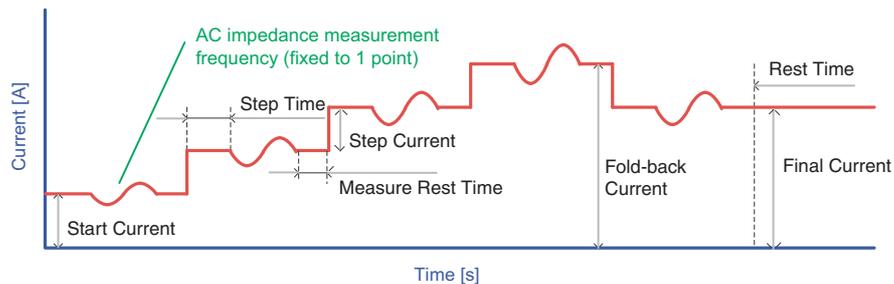
Fig.4-16 Conceptual diagram of I-V + AC impedance measurement

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Start Current		Sets the current at which the load current sweep is started.	*1
Enable current/voltage fold back		Select the check box to fold back the current sweep.	(No relevant values)
Fold-back Current		Sets the current at which the current sweep is folded back.	*1
Fold-back Voltage		Sets the voltage at which the current sweep is folded back. If the cell voltage is less than or equal to the fold-back voltage when the current sweep is increasing, the current sweep is folded back.	0 to 157.5 [V] or 0 to 15.75 [V]
Final Current		Sets the current at which the load current sweep is stopped.	*1
Step Current		Sets the step current for sweeping the load current in steps.	*1
Step Time		Sets the time for each step.	0 to 59 [min] 0 to 59 [s]
Measure Rest Time		Sets the rest time after the AC impedance measurement.	0 to 59 [s]
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Impedance Measurement Condition	Frequency	Sets the frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Measuring AC Current	Sets the measuring AC current used to measure the AC impedance.	0 to 10 [%] of the load current
	Measure Range	Sets the measurement range at which the AC impedance measurement is performed.	AUTO
	Moving Average	Sets the moving average count of the AC impedance measurement.	1 to 256 (1, 2, 4, 8, 16, 32, 64, 128, or 256)
Cutoff Condition	Repeat Count	Sets the number of times to repeat the AC impedance measurement.	1 to 999 times
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000 [V]
	Delta Current	The data before the load current value is changed is recorded.	(No relevant values)

*1.   Depends on the capacity of the electronic load unit that is being used.

4.9.3 I-V + Cole-Cole plot measurement

This test mode varies the load current in steps and performs Cole-Cole plot measurement (AC impedance) after the step time elapses.

1 In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2 In the **Test Mode** box, select **I-V + Cole-Cole Plot Measurement**.
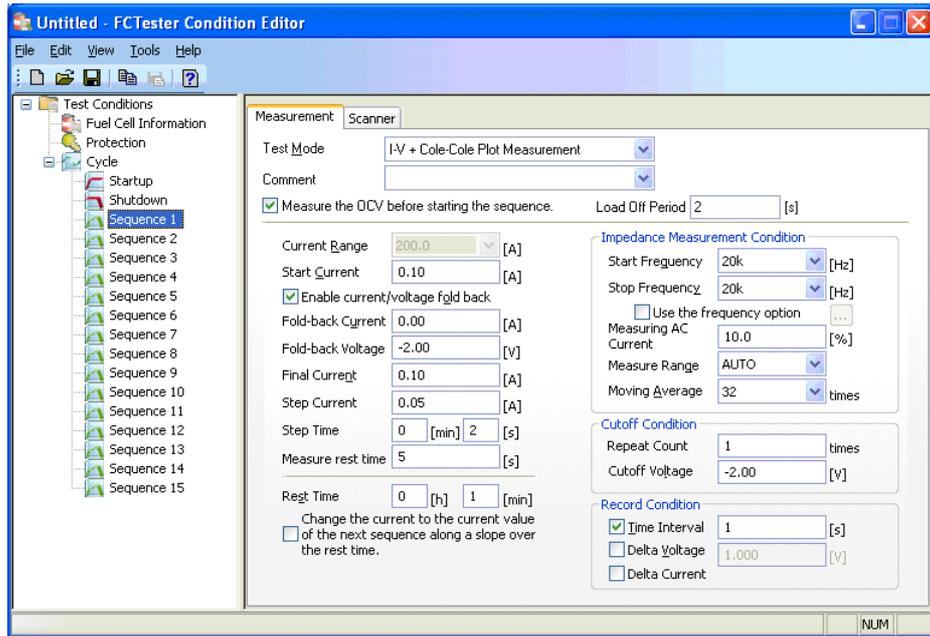
Fig.4-17 I-V + Cole-Cole plot measurement
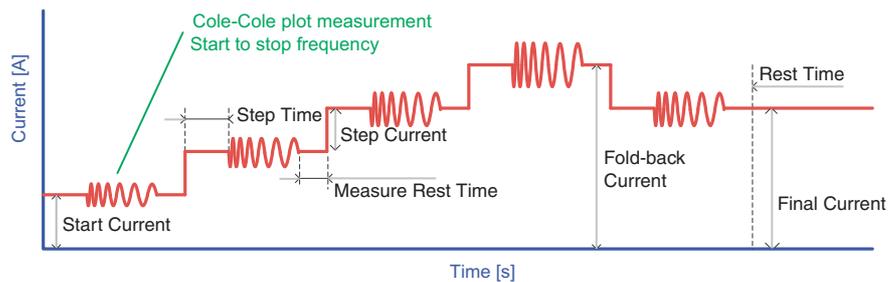
Fig.4-18 Conceptual diagram of I-V + Cole-Cole plot measurement

Item	Description	Input range
Comment	You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.	Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period	Sets the OCV measurement time.	1 to 60 [s]

Current Range		Selects the current range.	*1
Start Current		Sets the current at which the load current sweep is started.	*1
Enable current/voltage fold back		Select the check box to fold back the current sweep.	(No relevant values)
Fold-back Current		Sets the current at which the current sweep is folded back.	*1
Fold-back Voltage		Sets the voltage at which the current sweep is folded back. If the cell voltage is less than or equal to the fold-back voltage when the current sweep is increasing, the current sweep is folded back.	0 to 157.5 [V] or 0 to 15.75 [V]
Final Current		Sets the current at which the load current sweep is stopped.	*1
Step Current		Sets the step current for sweeping the load current in steps.	*1
Step Time		Sets the time for each step.	0 to 59 [min] 0 to 59 [s]
Measure Rest Time		Sets the rest time after the AC impedance measurement.	0 to 59 [s]
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Impedance Measurement Condition	Start Frequency	Sets the start frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Stop Frequency	Sets the stop frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Use the frequency option	Select the check box to click the [...] button. Press the [...] button to set the frequency in detail (Fig.4-19).	Frequency option
	Measuring AC Current	Sets the measuring AC current used to measure the AC impedance.	0 to 10 [%] of the load current
	Measure Range	Sets the measurement range at which the AC impedance measurement is performed.	AUTO
	Moving Average	Sets the moving average count of the AC impedance measurement.	1 to 256 (1, 2, 4, 8, 16, 32, 64, 128, or 256)
Cutoff Condition	Repeat Count	Sets the number of times to repeat the AC impedance measurement.	1 to 999 times
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]
	Delta Current	The data before the load current value is changed is recorded.	(No relevant values)

*1.   Depends on the capacity of the electronic load unit that is being used.

■ **Frequency option**
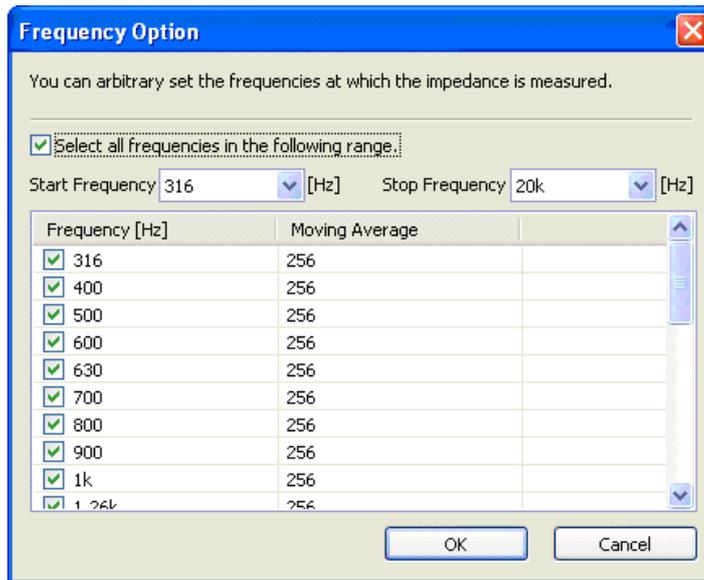
Fig.4-19   Frequency Option

Select the check box to select the frequency individually. The start and stop frequencies are interlinked to the frequency selected using the check boxes.

The moving average shows the value specified for moving average in the impedance measurement condition.

4.9.4   V-I Measurement

This test mode varies the load voltage in steps and measures the current.

1   In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2   In the **Test Mode** box, select **V-I measurement**.
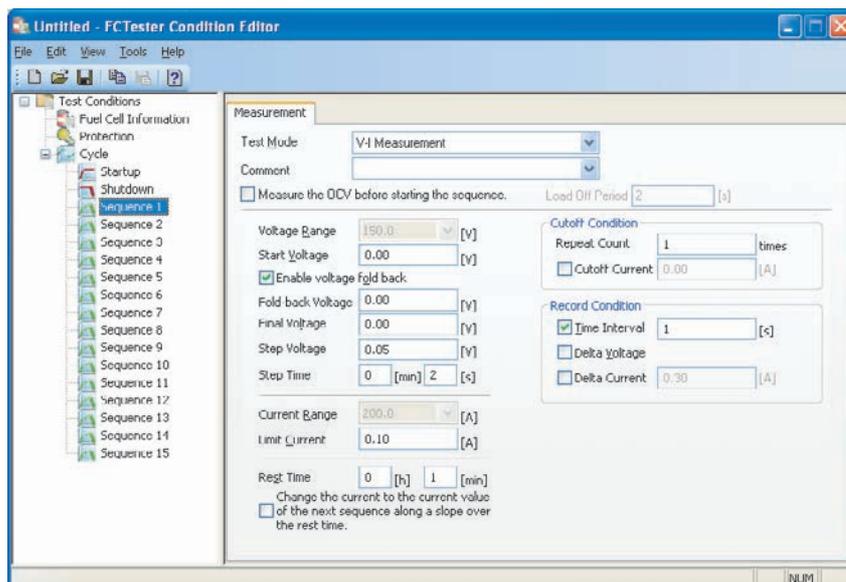
Fig.4-20   V-I measurement
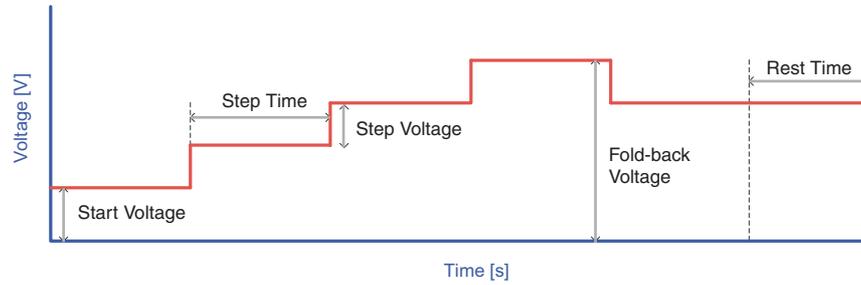
Fig.4-21   Conceptual diagram of V-I measurement

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Voltage Range		Selects the voltage range.	15.0 or 150.0 [V]
Start Voltage		Sets the voltage at which the voltage sweep is started.	0 to 157.5 [V] or 0 to 15.75 [V]
Enable voltage fold back		Select the check box to fold back the voltage sweep.	(No relevant values)
Fold-back Voltage		Sets the voltage at which the voltage sweep is folded back.	
Cutoff Voltage		Sets the voltage at which the voltage sweep is stopped.	
Step Voltage		Sets the step voltage for sweeping the voltage in steps.	
Step Time		Sets the time for each step.	0 to 59 [min] 0 to 59 [s]
Current Range		Selects the current range.	*1
Limit Current		Sets the limit current.	
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Cutoff Condition	Repeat Count	Sets the number of times to repeat the V-I test.	1 to 999 times
	Cutoff Current	The sequence is terminated if the current falls to or below the cutoff current when the operation mode is constant voltage.	
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	The data before the voltage is changed is recorded.	
	Delta Current	If the difference between the previous current data and the present current data is greater than or equal to the delta current, the data is recorded.	*1

*1.   Depends on the capacity of the electronic load unit that is being used.

4.9.5 Cole-Cole Plot Measurement

This test mode sweeps the frequency in steps and measures the impedance.

The graph shows a Cole-Cole plot.

1 In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2 In the **Test Mode** box, select **Cole-Cole plot measurement**.
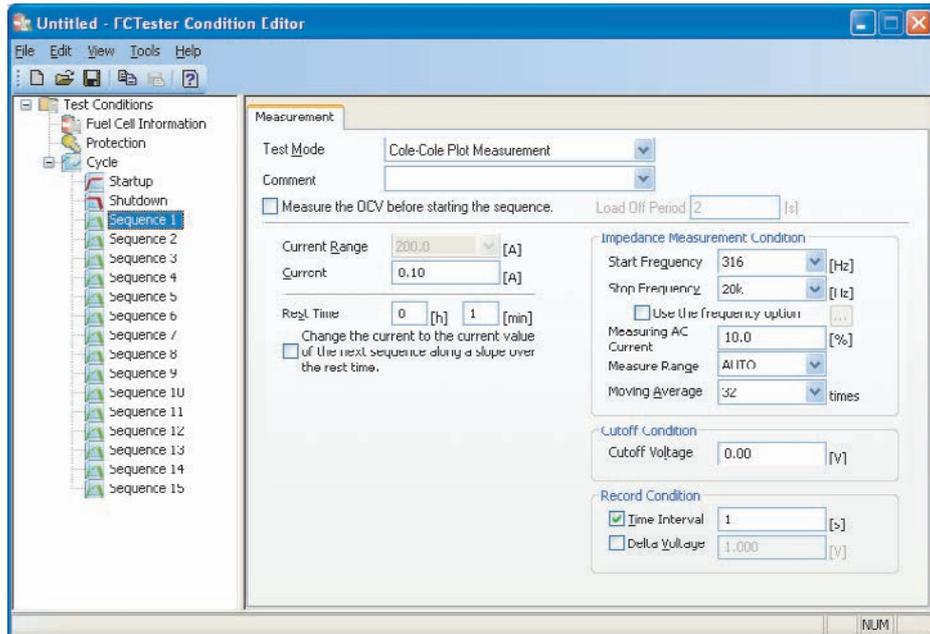
Fig.4-22   Cole-Cole plot measurement
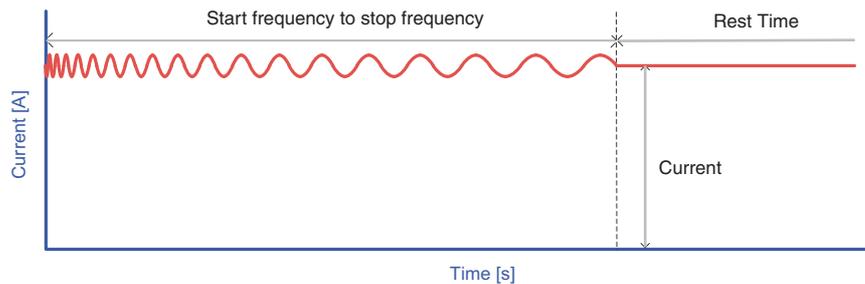
Fig.4-23   Conceptual diagram of Cole-Cole plot measurement

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Current		Sets the load current.	*1
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Impedance Measurement Condition	Start Frequency	Sets the start frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Stop Frequency	Sets the stop frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Use the frequency option.	Select the check box to click the […] button. Press the […] button to set the frequency in detail (Fig.4-19).	Frequency option
	Measuring AC Current	Sets the measuring AC current used to measure the AC impedance.	0 to 10 [%] of the load current
	Measure Range	Sets the measurement range at which the AC impedance measurement is performed.	AUTO
	Moving Average	Sets the moving average count of the AC impedance measurement.	1 to 256 (1, 2, 4, 8, 16, 32, 64, 128, or 256)
Cutoff Condition	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]

*1.   Depends on the capacity of the electronic load unit that is being used.

4

Creating Test Conditions

4.9.6   AC impedance measurement

This mode measures the impedance at arbitrary frequency points continuously during the generating time.

1   In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2   In the **Test Mode** box, select **AC Impedance Measurement**.
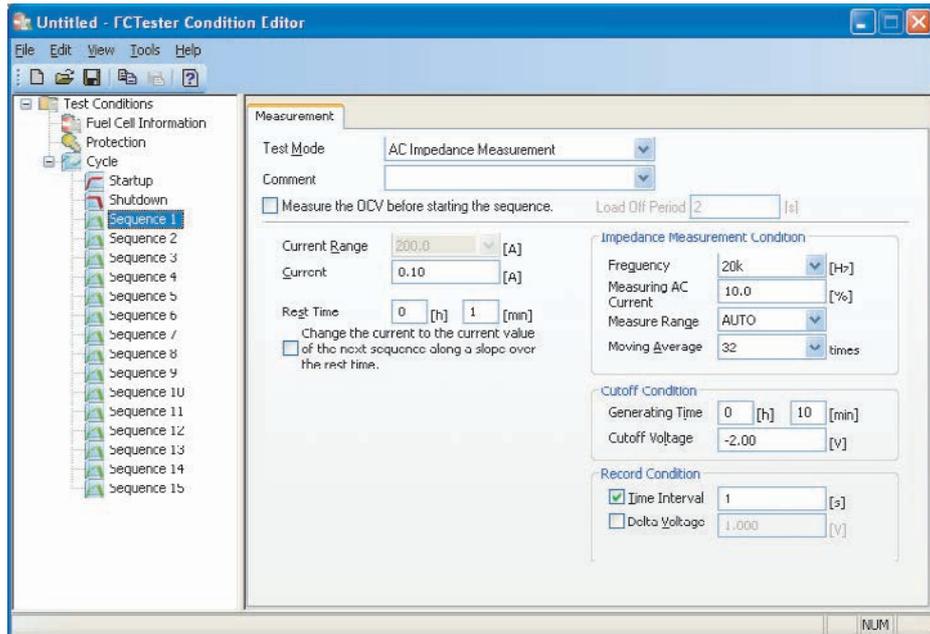
Fig.4-24   AC impedance measurement
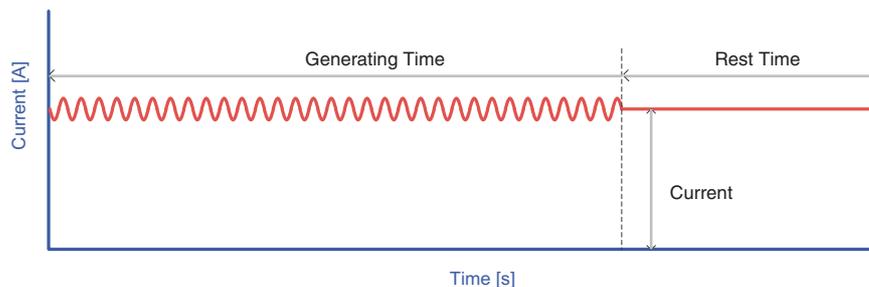
Fig.4-25   Conceptual diagram of AC impedance measurement

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Current		Sets the load current.	*1
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Impedance Measurement Condition	Frequency	Sets the frequency at which the AC impedance measurement is performed.	10m to 20k [Hz]
	Measuring AC Current	Sets the measuring AC current used to measure the AC impedance.	0 to 10 [%] of the load current
	Measure Range	Sets the measurement range at which the AC impedance measurement is performed.	AUTO
	Moving Average	Sets the moving average count of the AC impedance measurement.	1 to 256 (1, 2, 4, 8, 16, 32, 64, 128, or 256)
Cutoff Condition	Generating Time	Sets the generating time during which power is generated in the sequence.	0 to 8 [h] 0 to 59 [min]
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]

*1. Depends on the capacity of the electronic load unit that is being used.

4.9.7 Current Interrupt Measurement

This mode measures the internal resistance using the current interrupt method. The measurement is repeated by the specified repeat count.

1 In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2 In the **Test Mode** box, select **Current Interrupt Measurement**.
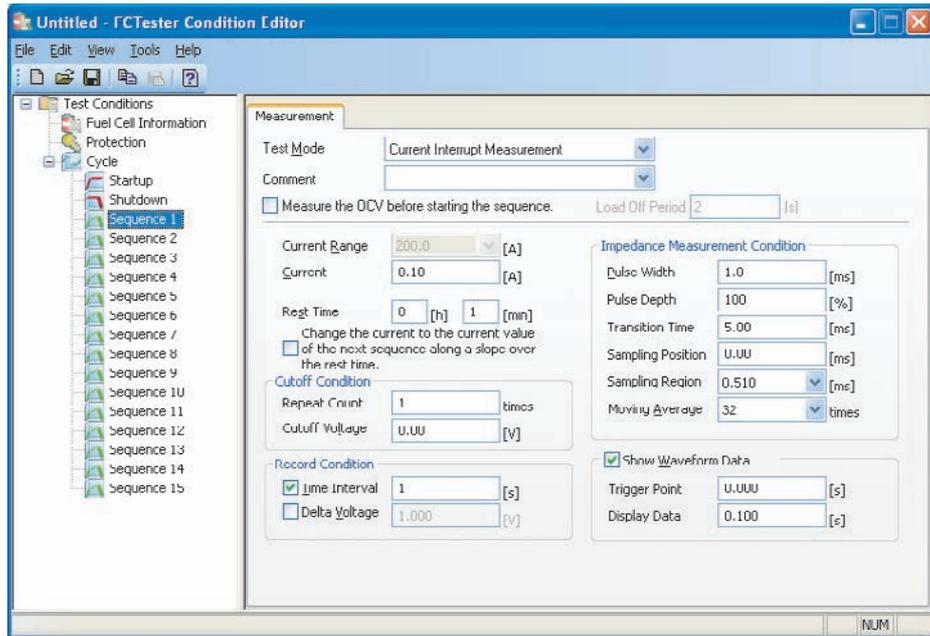
Fig.4-26   Current interrupt measurement

Time [s]
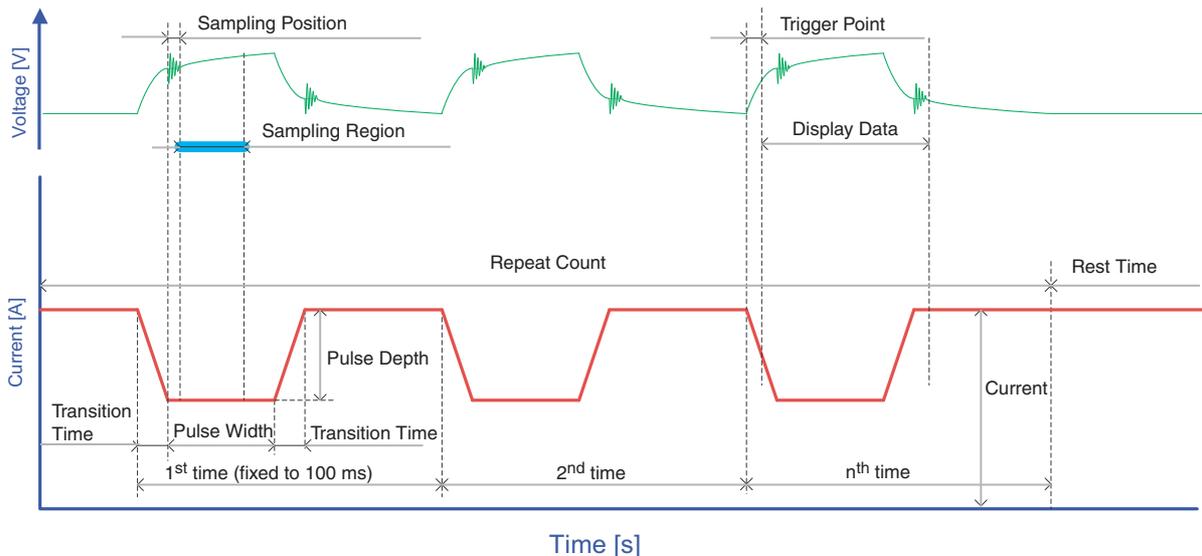
Fig.4-27   Conceptual diagram of current interrupt measurement

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NOTE
• The waveform shows the voltage and current data of the last current interrupt.

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Current		Sets the load current.	*1
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Impedance Measurement Condition	Pulse Width	Sets the pulse width of the current interrupt method.	0.1 to 10.0 [ms]
	Pulse Depth	Sets the pulse depth of the current interrupt method.	0 to 100 [%]
	Transition Time	Sets the transition time of the current interrupt method.	0.00 to 10.00 [ms]
	Sampling Position	Sets the sampling start position of the current interrupt method.	0.00 to 9.99 [ms]
	Sampling Region	Sets the sampling region of the current interrupt method.	0.002, 0.006, 0.014, 0.030, 0.062, 0.126, 0.254, or 0.510 [ms]
	Moving Average	Sets the moving average count of the AC impedance measurement.	1 to 256 (1, 2, 4, 8, 16, 32, 64, 128, or 256)
Cutoff Condition	Repeat Count	Sets the number of times to repeat the current interrupt method.	1 to 999 times
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]
Show Waveform Data		Select the check box to show the voltage and current waveforms of the current interrupt method.	(No relevant values)
Trigger Point		Sets the point to start the waveform acquisition.	0.000 to 0.100 [s]
Display Data		Sets the time for displaying the waveform.	0.000 to 0.100 [s]

*1. Depends on the capacity of the electronic load unit that is being used.

4.9.8   Constant Current Test

This mode performs constant current measurement during the generating time.

1   In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2   In the **Test Mode** box, select **Constant Current Test**.
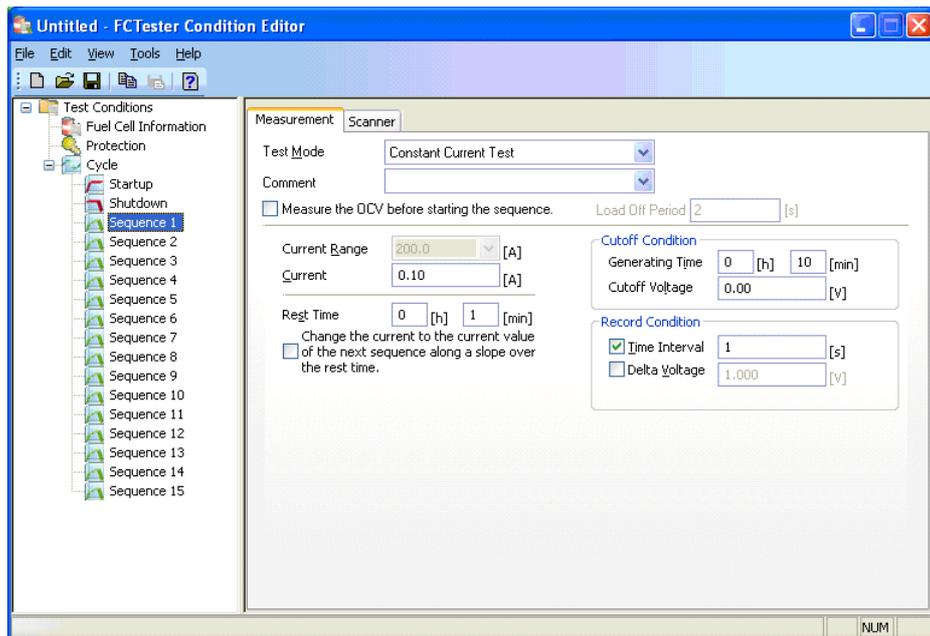
Fig.4-28   Constant current test

Fig.4-29   Conceptual diagram of constant current test

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Current		Sets the load current.	*1
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Cutoff Condition	Generating Time	Sets the generating time during which power is generated in the sequence.	0 to 12 [h] 0 to 59 [min]
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]

*1.   Depends on the capacity of the electronic load unit that is being used.

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Creating Test Conditions

4.9.9   Constant Voltage Test

This mode performs constant voltage measurement during the generating time.

1   In the Test Condition Item Pane, click **Sequence (1 to 15)**.

You can select any of the sequences from 1 to 15 in the Test Conditions Item Pane. Select the sequence considering the cycle order.

2   In the **Test Mode** box, select **Constant Current Test**.
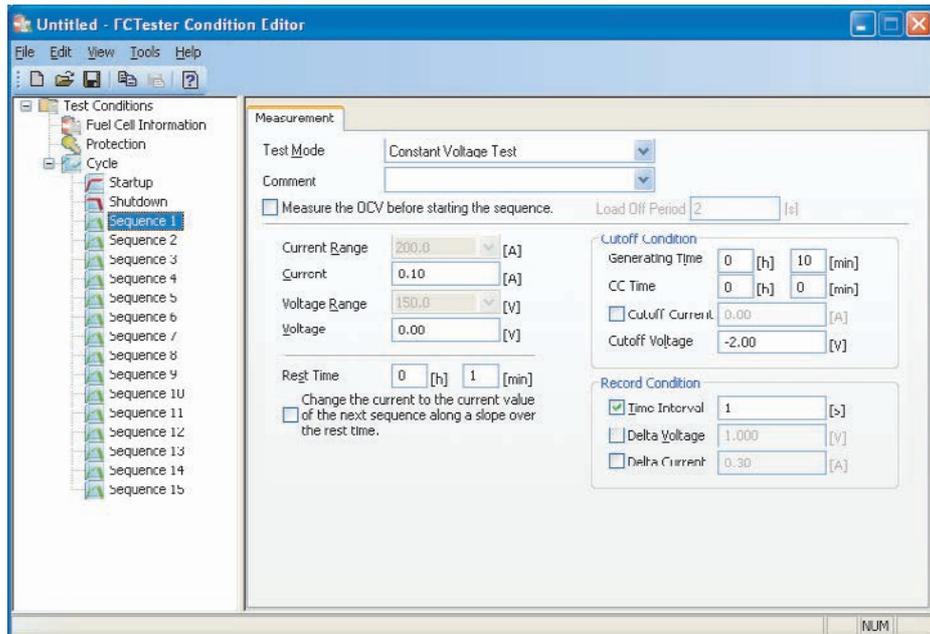
Fig.4-30   Constant voltage test
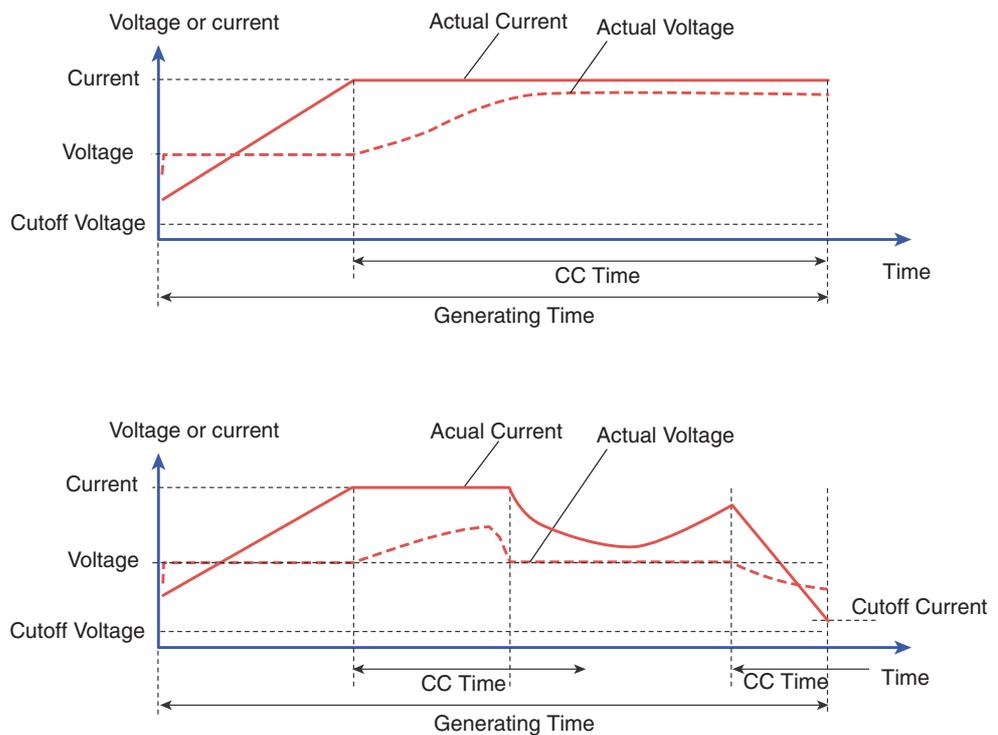
Fig.4-31   Conceptual diagram of constant voltage test

Item		Description	Input range
Comment		You can enter up to 16 arbitrary characters. You can enter more than 16 characters, but they are discarded. Past comments are stored and displayed in the drop-down list when you click the arrow.	
Measure the OCV before starting the sequence.		Select the check box to set the fuel cell to no load condition (open circuit) and measure the cell voltage. The load is turned off, and the OCV (Open Circuit Voltage) is measured before starting each sequence.	(No relevant values)
Load Off Period		Sets the OCV measurement time.	1 to 60 [s]
Current Range		Selects the current range.	*1
Current		Sets the upper limit of the load current.	*1
Voltage Range		Selects the voltage range.	15.0 [V] or 150.0 [V]
Voltage		Sets the voltage.	0 to 157.5 [V] or 0 to 15.75 [V]
Rest Time		Sets the rest time after the sequence sheet is completed.	0 to 12 [h] 0 to 59 [min]
Change the current to the current value of the next sequence along a slope over the rest time.		The current is changed from the value at the end of the sequence sheet to the start current of the next sequence sheet during the rest time. The load current is changed in steps at 1 second interval.	(No relevant values)
Cutoff Condition	Generating Time	Sets the generating time during which power is generated in the sequence.	0 to 12 [h] 0 to 59 [min]
	CC Time	Sets the time from the point when the limit current is reached. If the current falls below the limit current within the specified time, the specified time is reset.	0 to 8 [h] 0 to 59 [min]
	Cutoff Current	The sequence is terminated if the current falls to or below the cutoff current when the operation mode is constant voltage.	*1
	Cutoff Voltage	The sequence is terminated, if the cell voltage falls to or below the cutoff voltage.	-2 to 150 [V]
Record Condition	Time Interval	Sets the time interval for acquiring data.	1 to 3600[s]
	Delta Voltage	If the difference between the previous voltage data and the present voltage data is greater than or equal to the delta voltage, the data is recorded.	0.001 to 1.000[V]
	Delta Current	If the difference between the previous current data and the present current data is greater than or equal to the delta current, the data is recorded.	*1

*1. Depends on the capacity of the electronic load unit that is being used.

Executing Tests

This chapter describes the FCTester Executive (test execution program).

5.1 About the FCTester Executive

FCTester Executive executes the tests according to the test conditions that you create with the Condition Editor.

The FCTester Executive provides the following functions.

- Load test conditions and display a brief summary of the conditions
- Execute tests
- Display and save the measured data

■ Starting the FCTester Executive

On the taskbar, click the Start button, and then select **Programs > kikusui Fuel Cell Tester 1.1 > FCTester Executive**.

The following window opens.

Test Conditions and
Test Data Tree Pane

Toolbar

Graph and Data Pane

Status monitor

Monitor and Event Log Pane
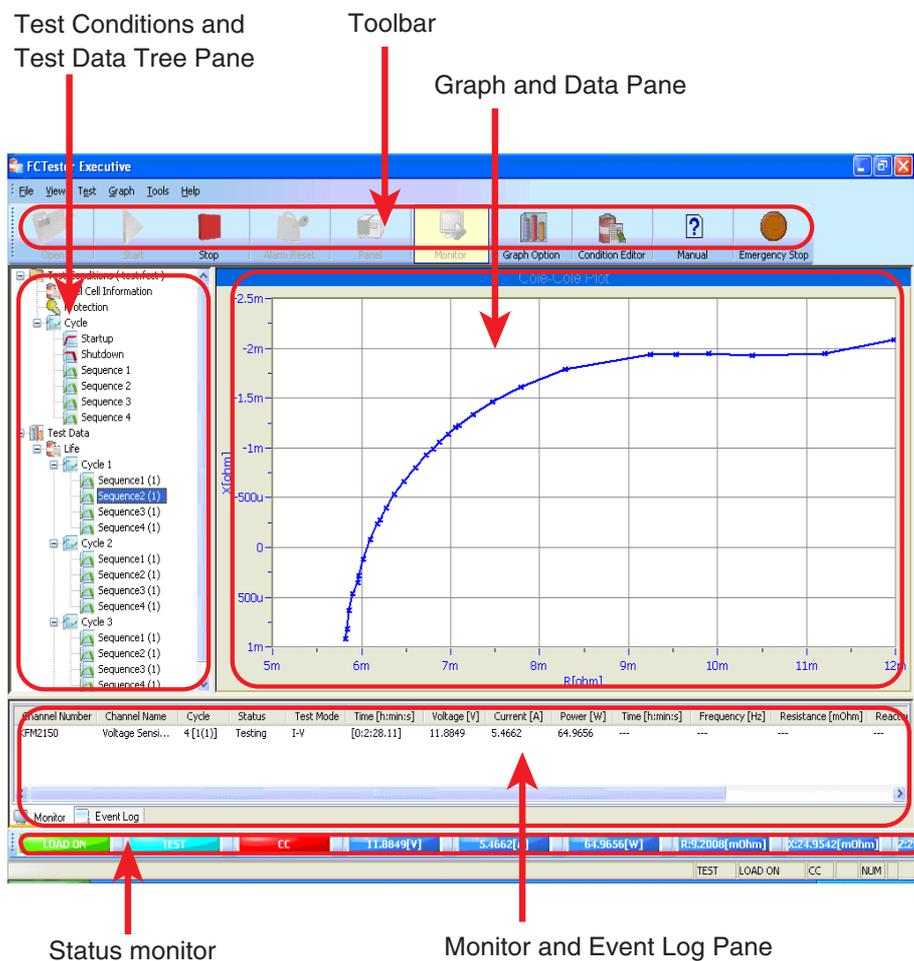
Fig.5-1   Startup window

Fig.5-2   Toolbar

5.2 Window Description

Table 5-1   Window structure

Window	Description
Test Conditions and Test Data Tree Pane	Displays the current test conditions and the status of the test data in a tree structure.
Graph and Data Pane	Displays the item selected in the Test Conditions and Test Data Tree Pane.
Monitor and Event Log Pane	Displays the monitored value of the voltage and impedance. The Event Log displays the operation log such as test start and abort.
Toolbar	Items that are used often are indicated as icons. The following icons are available: Open, Close, Stop, Alarm Reset, Panel, Monitor Start, Option, Test Conditions, Manual, and Emergency Stop.
Status monitor	Displays the main information of the KFM2150 (load on, operation mode of the electronic load unit, voltage, and current).

5.2.1   Test Conditions and Test Data Tree Pane

When the FCTester Executive is started, only the Test Conditions and Test Data are displayed.

Test condition items

When you load test conditions by choosing **Open** from the **File** menu, a tree similar to the one in the Condition Editor is displayed.

- The sequence sheets (1 to 15) whose check box is selected in the test cycle sequence in the Condition Editor cycle are displayed.
- Startup and Shutdown are displayed even if it is disabled in the cycle setting of the Condition Editor.

Test data items

Items such as life and cycle are displayed as the test progresses.

Displays only the sequence sheets that are to be used.
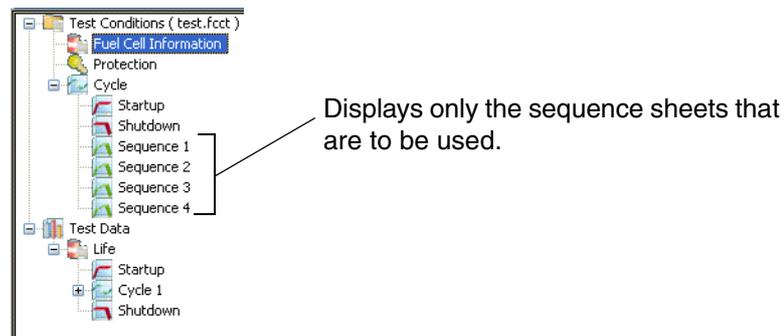
Fig.5-3   Test Conditions and Test Data Tree Pane

5.2.2   Graph and Data Pane

Test conditions display

When you select a test condition item on the Test Conditions and Test Data Tree Pane, the contents in Table 5-2 are shown.

Table 5-2   Test conditions

Item			Displayed contents
Test conditions			Test conditions created using the FCTester Condition Editor (displays the settings of each sheet item).
	Fuel Cell Information		
	Protection		
	Cycle		
		Startup	
		Shutdown	
		Sequence 1 to 15	

For the procedure to change the test conditions, see section 5.3.4, ⅹ Changing Test Conditions during the Test.

Test data display

When you select a test data item on the Test Conditions and Test Data Tree Pane, the contents in Table 5-3 are shown.

Table 5-3   Test data

Item					Displayed contents
Test Data					Real-time graph of the test currently in progress.
	Life				Displays the result after each sequence is completed. (Finished By, Test Mode, Elapsed Time, Start Time, Start Voltage, Start Current, Start Resistance, Start Reactance, Start Impedance, Start Phase, Finish Voltage, Finish Current, Finish Resistance, Finish Reactance, Finish Impedance, and Finish Phase)
		Cycle n			Displays the result after each sequence is completed.
			Sequence n (m)		Without the scanner option: Displays the graph of this sequence.
					With the scanner option: Displays the graph of the stack channel of this sequence.
				Scanner	With the scanner option: Displays the graphs of multiple channels of this sequence (excluding the stack channel).
					Channel (n)	With the scanner option: Displays the graph of channel n of this sequence.

■ **Test data**

Displays the real-time graph of the test currently in progress. The graph is shown in the format corresponding to the test mode and sequence.

The graph displays up to 64 data values. For current interrupt measurement, the last waveform data during the current interrupt measurement is displayed. If the scanner option is enabled, the last waveform data of the first selected channel is displayed.
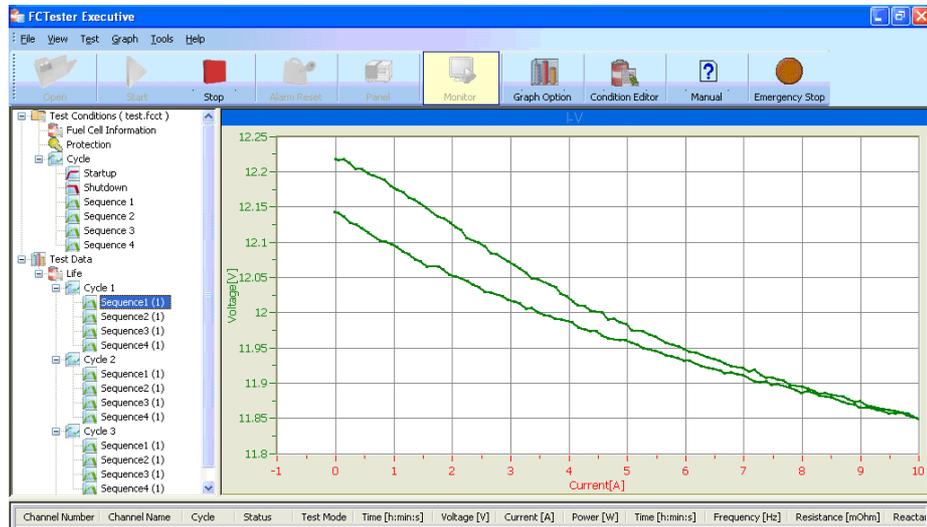
Fig.5-4   I-V measurement example

■ **Life**

Displays a simple result of the finished sequence.

A portion of the data such as OCV (Open Circuit Voltage) is displayed for the sequence that is in progress. Startup and shutdown sequences are not displayed.

Fig.5-5   Result display of the finished sequences

■ Cycle n

Displays a simple result of the sequences in the cycle.
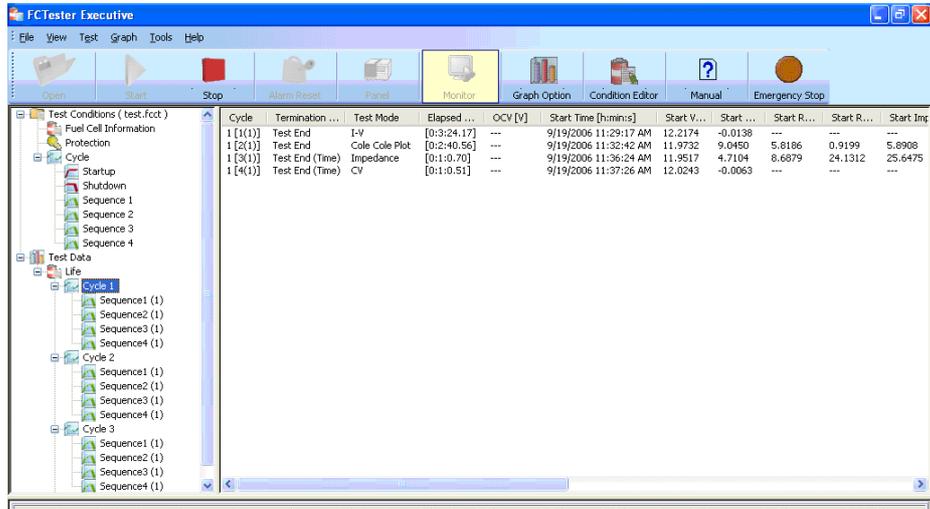
Fig.5-6   Result display of cycles 1 to 5

■ Sequence n (m) (without the scanner option)

Displays the graph of the measured sequence.
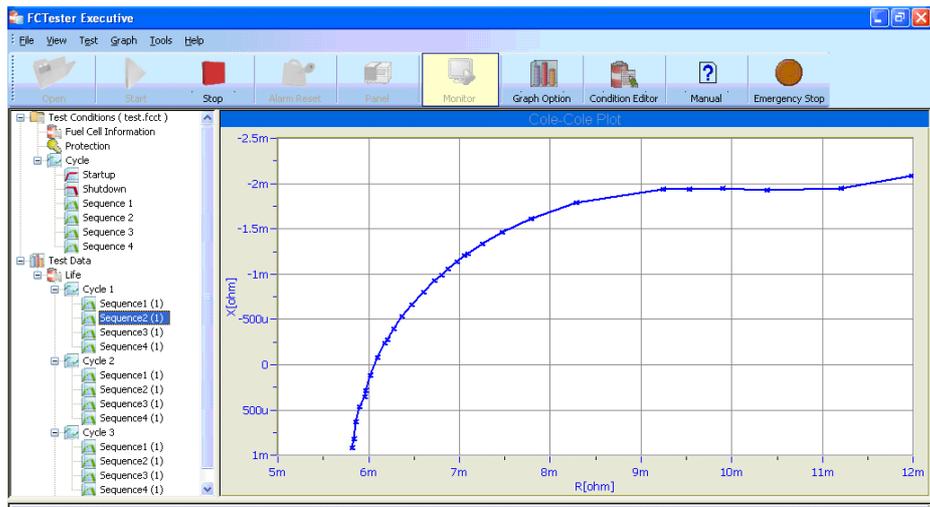
Fig.5-7   Graph display of the sequence

Sequence n (m)

Repeat count

Sequence number
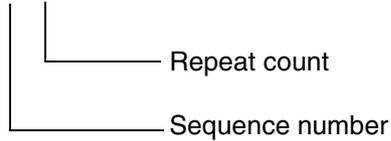
■ Sequence n (m) (with the scanner option)

Displays the graph of the stack channel of the measured sequence.
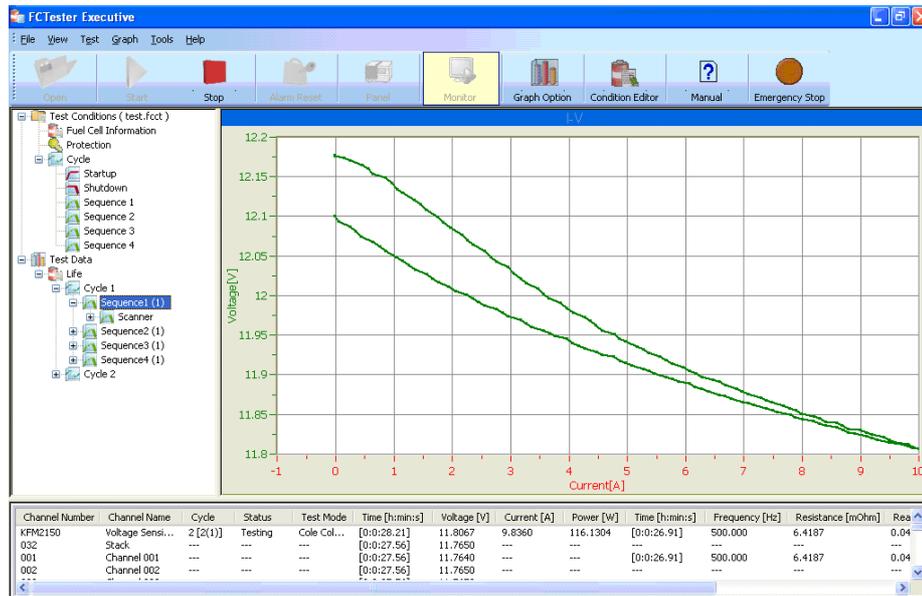
Fig.5-8   Display example of a stack channel graph

Sequence n (m)

Repeat count

Sequence number
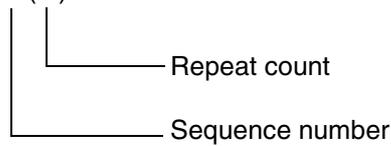
■ Scanner (with the scanner option)

Displays the multiple channel graph of the measured sequence.
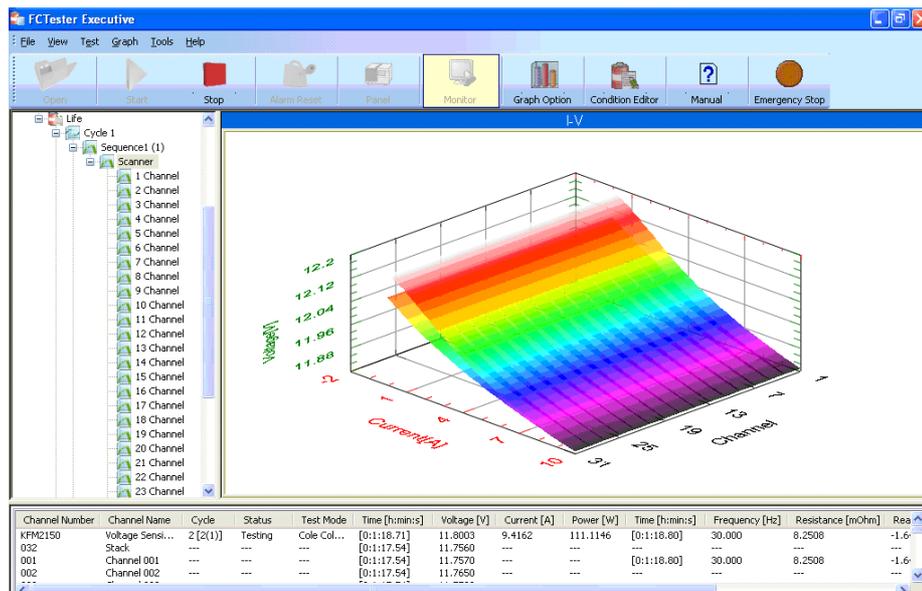
Fig.5-9   Display example of a multiple channel graph

■ **Channel n (with the scanner option)**

Displays the channel graph of the measured sequence.
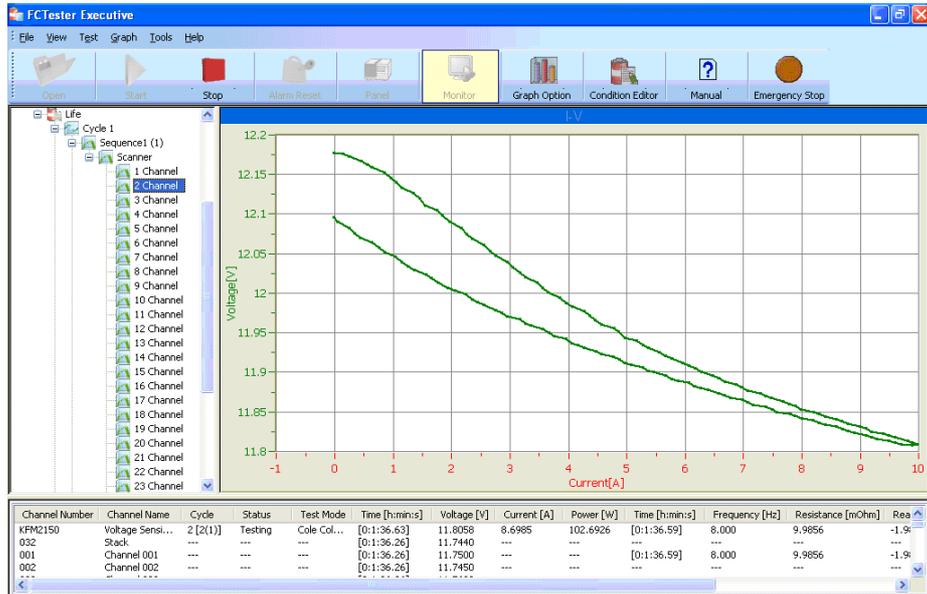
Fig.5-10   Channel graph display example

5.2.3   Monitor and Event Log Pane

If the **Monitor** tab is selected, the monitored values of the voltage and impedance of the test currently in progress are displayed.

If **Monitor** is enabled, the voltage and current are monitored even when the test is not in progress.
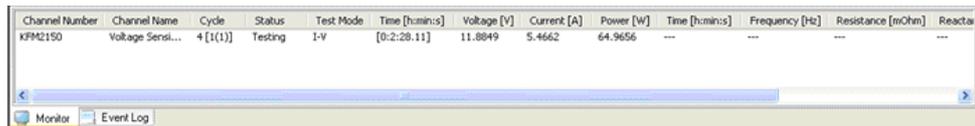
Fig.5-11   Real-time monitor

If the **Event Log** is selected, the operation log from when the application is started is displayed.
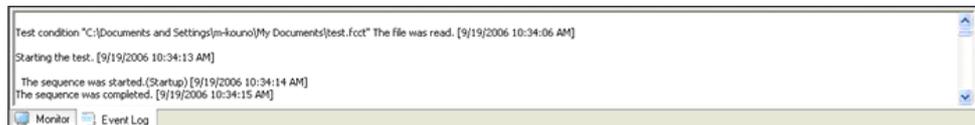
Fig.5-12   Event log

5.3 Executing Tests

5.3.1 Using the Startup Sequence

If the **Use the startup sequence** check box is selected in the Cycle setting of the test conditions using the Condition Editor.

Starting the test

Start the test according to the procedure below.
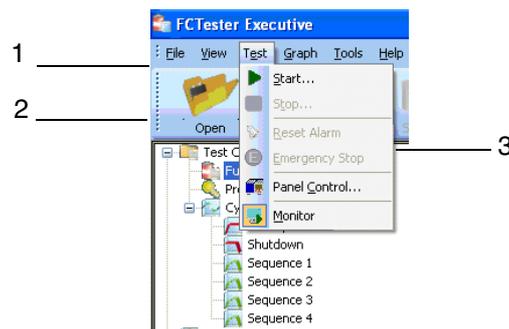
Fig.5-13   Test menu

1 From the **File** menu, select **Open**.

2 Select the test conditions file you want to load from the Open window.

When the file is loaded, the test condition items are displayed in a tree structure on the Test Conditions and Test Data Tree Pane.

3 From the **Test** menu, select **Monitor**.

You can start the test only when the monitor is started.

You can check whether the monitor has started on the **Monitor** tab on the Monitor and Event Log Pane. If the voltage and current are updated on the Pane, the monitor is running.

4 Select **Start** from the **Test** menu or click Start on the toolbar.

The Start dialog box opens.
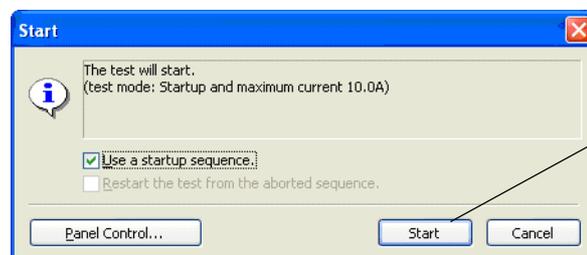
Fig.5-14   Start

If **Start** is not available, see "Starting the test without the startup sequence" on the next page.

5 Click **Start**.

When the test starts, the windows shown in Fig.5-15 appears.

Test Data is selected automatically on the Test Conditions and Test Data Tree Item Pane, and the Graph and Data Pane displays the real-time graph of the test currently in progress.

The status monitor displays TEST.
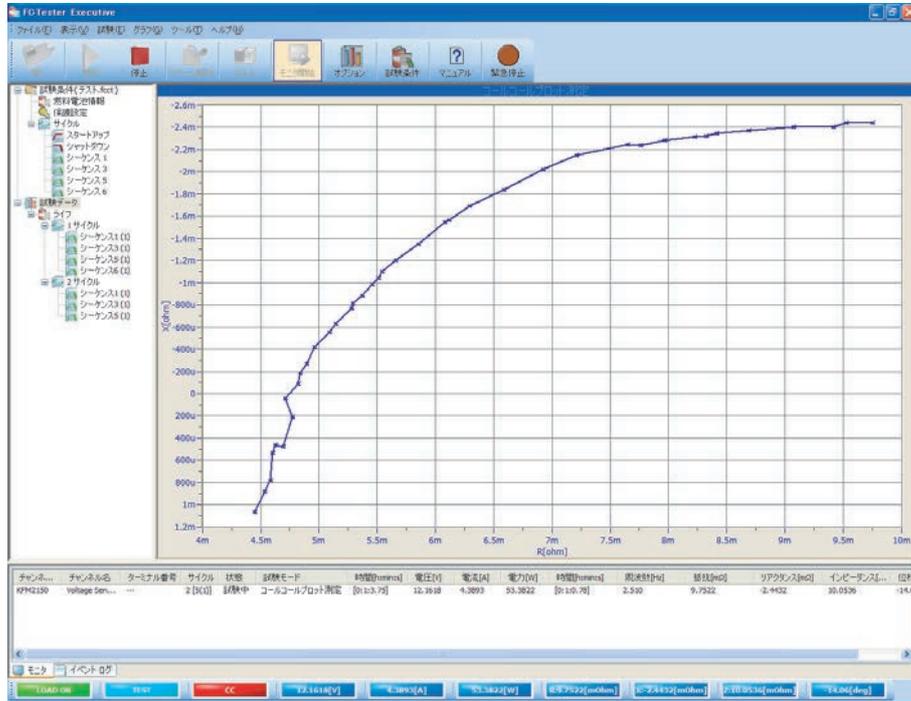
Fig.5-15   Test data display

5.3.2   Not Using the Startup Sequence

If the **Use the startup sequence** check box is cleared in the Cycle setting of the test conditions using the Condition Editor. Load on/off, load current setting, and soft start function are controlled from the Panel Control.

This is useful if you want to start the test after checking the status of the fuel cell operation. You can set the load current from the Panel Control and check the operation status before starting the test using sequences.

Starting the test

1   Carry out steps 1 to 4 in section 5.3.1, ﾒ Using the Startup Sequence."

The **Start** button in the Start dialog box is unavailable.
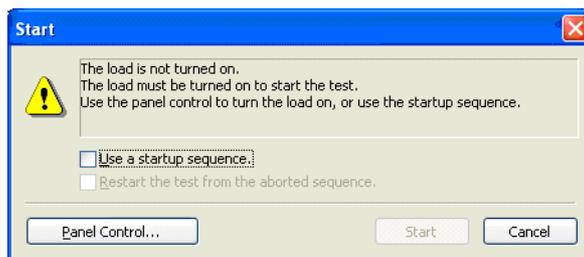
Fig.5-16   When Start is unavailable

2 In the Start dialog box, click **Panel Control**.

The Panel Control dialog box appears.
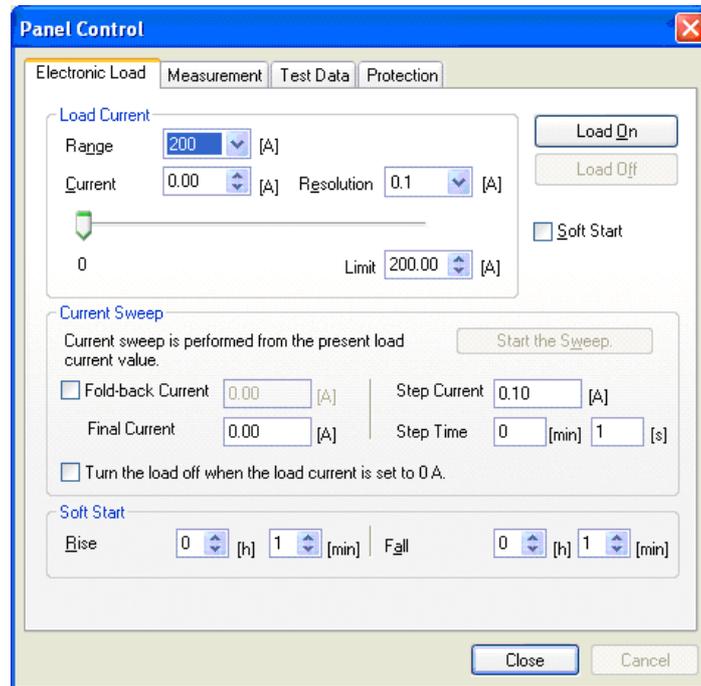
Fig.5-17   Panel Control

If you want to start the test from a specific load current (not 0 A), carry out the procedure below in the **Electronic Load** page.

3 Select the load current range of the electronic load unit.

4 Type the load current value.

■ **When not using the soft start function**

5 Click **Load On**.

The load of the electronic load unit turns on, and the load current flows. Click **Load Off** to turn the load off.

6 Click **Close**.

The Start dialog box shown in Fig.5-16 appears.

7 Click **Start**.

The test starts.

■ **When using the soft start function**

5 Select the **Soft Start** check box.

6 Type in values of **Rise** Time and **Fall** Time.

7 Click **Load On**.

The load of the electronic load unit turns on, and the soft start function starts.

Executing Tests

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8. Click **Close**.

The Start dialog box shown in Fig.5-16 appears. The **Start** button is unavailable until the rise time elapses.

9 When the **Start** button becomes available, click it.

The test starts.

5.3.3   Adding a startup sequence at the start of the test

You can add a startup sequence to start the test even if the startup sequence is disabled in the loaded test conditions.

1 Carry out steps 1 to 4 in section 5.3.1, ⅹ Using the Startup Sequence.

The **Start** button in the Start dialog box is unavailable.

2 In the Start dialog box of Fig.5-16, select the **Use a startup sequence.** check box.

The **Start** button becomes available.

3 Click **Start**.

The test starts.

5.3.4   Changing Test Conditions during the Test

From the **Tools** menu, select **Options**. If you select the **Change the test conditions during the test** check box, the test conditions file that is currently loaded in the Test Executive is reloaded after the current sequence is finished.

If you edit and overwrite the current test conditions, the new test conditions are applied from the next sequence.
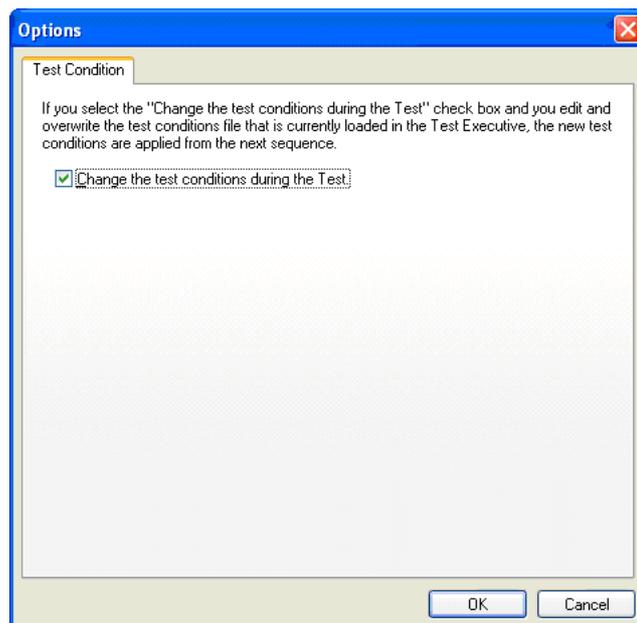
Fig.5-18   Options Window

5.3.5 Stopping the Test

The following two methods are available to stop a test in progress.

Fig.5-19   Stop and Emergency Stop on the toolbar

Emergency Stop

Select Emergency Stop if you want to stop the test immediately.

1   Select **Emergency Stop** from the **Test** menu or click **Emergency Stop** on the toolbar.

The test stops, and the load of the electronic load unit is turned off.

Stop

Select **Stop** if you want to stop the test under a given condition.

If you select Stop, the load of the electronic load unit does not turn off automatically. You must manually turn the load off.

If the test conditions include the shutdown sequence or if you enable **Use the startup sequence** in the Start dialog box, the load of the electronic load unit turns off when the test stops.

1   Select **Stop** from the **Test** menu or click **Stop** on the toolbar.

The Stop dialog box opens.
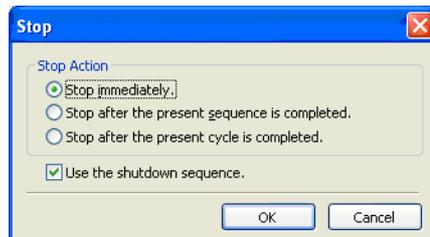
Fig.5-20   Stop

2   Select the stop action and click **OK**.

If the loaded test conditions do not include the shutdown sequence, you can enable it by selecting the **Use the shutdown sequence** check box in the Stop dialog box. In this case, the shutdown sequence is executed after the selected stop action. Then, the test stops, and the load of the electronic load unit is turned off.

5.3.6 Alarm Occurrence

If a protection function is activated during a test, an alarm occurs, and the test stops. The status display of the Monitor and Event Pane indicates the word Alarm.

Fig.5-21   Alarm occurrence

Reset Alarm

Fig.5-22   Reset Alarm on the toolbar

To reset an alarm, carry out the procedure below.

1   Select **Reset Alarm** from the **Test** menu or click **Reset Alarm** on the toolbar.

> The alarm is reset, and you can execute the test again. Eliminate the cause of the alarm before you execute the test again.

5.3.7 Test Completion

The test is complete when all the cycles specified in the test conditions are finished.

The status monitor switches from TEST to IDLE.

If you want to execute the test again using the same test conditions, you can simply start the test.

If you want to change the test conditions, load a new test conditions file. Because the monitor is already started, you can immediately start the test after the test conditions are loaded.

Load off

The load remains on if the shutdown sequence is not used. To turn the load off, carry out the procedure below.

1   From the **Test** menu, select **Panel Control**.

> The Panel Control dialog box opens. Carry out the following steps in the Electronic Load page.

2   Click **Load Off**.

> The load of the electronic load unit turns off.

3   Click **Close**.

5.4   Panel Control

Panel Control consists of the Electronic Load, Measurement, Test Data, and Protection pages. It allows you to carry out operations equivalent to the operations on the KFM2150. In addition, you can perform current sweep (I-V measurement) and frequency sweep (Cole-Cole plot measurement). Panel Control cannot be used if a test is being executed according to the procedure given in section 5.3, ⅄ Executing Tests."

■ Basic operation

• From the **Test** menu, select **Panel Control**.

• There is no need to set test conditions using the Condition Editor.

• Press the up and down keys for the setup items with spin control to change the value. The value is immediately applied.

• If you enter the value directly in the text box, the value is applied when you press the Enter key in the text box.

• If you do not press the Enter key, the value is not applied to the KFM2150. However, it is applied if you move to another tab page or if you press the Close button.

5.4.1   Electronic Load page

■ Load current

Set the current range and load current. If you set the current limit, you will not be able to set a current higher than the limit. This prevents you from setting an incorrect load current. You can also set the current using the slider control. Resolution specifies the resolution in which the load current is changed when you press the up and down keys.

■ Current Sweep

Click **Start the sweep** to perform a load current sweep from the present preset current by the specified step unit. The operation is equivalent to the I-V sequence. If you want to stop the current sweep, click **Stop the sweep**. The test stops in that condition. Operation on other pages is prohibited while the current sweep is in progress.

■ Soft Start

You can use the soft start function of the KFM2150 by select the **Soft Start** check box and turning the load on/off.

If you change the rise or fall time during the soft start operation, the rise or fall time changes. If you set the rising or falling time to 0 s, the load turns on/off.
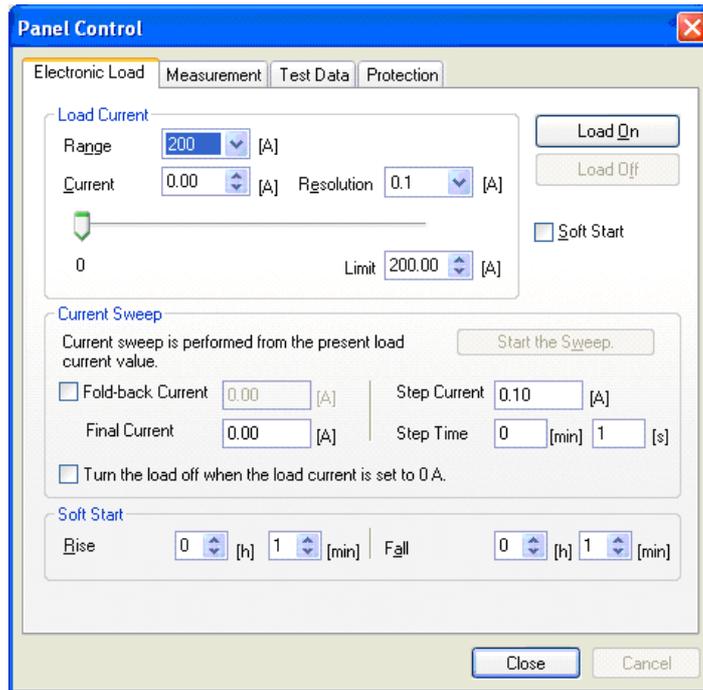
Fig.5-23   Electronic load page

5.4.2   Measurement page

Set the conditions for the AC impedance and current interrupt measurements.

Click **Start the sweep** to perform a measuring frequency sweep from the present preset frequency to the stop frequency. If you want to stop the frequency sweep, click **Stop the sweep**. The test stops in that condition. Operation on other pages is prohibited while the current sweep is in progress.
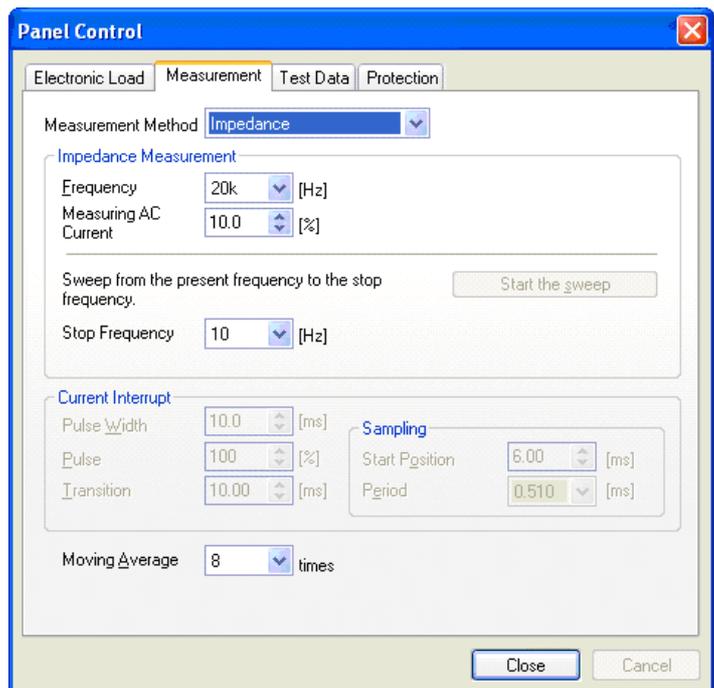
Fig.5-24   Measure page

5.4.3 Test Data page

The measured data is saved according to the record conditions from the time you select the **Start Recording** check box until you clear the check box. If you start a current or frequency sweep, a test conditions file is created automatically according to the specified record conditions.

The data file of the simplified measurement on the Panel Control is created in the test data folder.
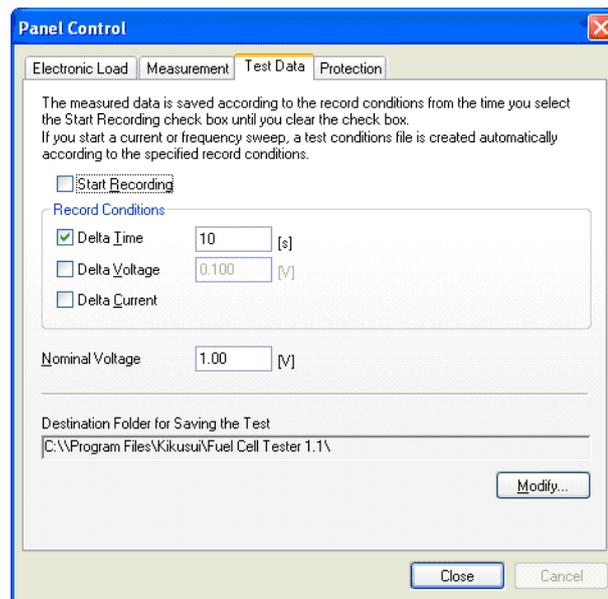
Fig.5-25   Test Data page

5.4.4 Protection page

Set the KFM2150 protection. If clear a check box, the protection function is turned off. If you clear the Impedance UVP check box, the voltage is set to -2 [V].
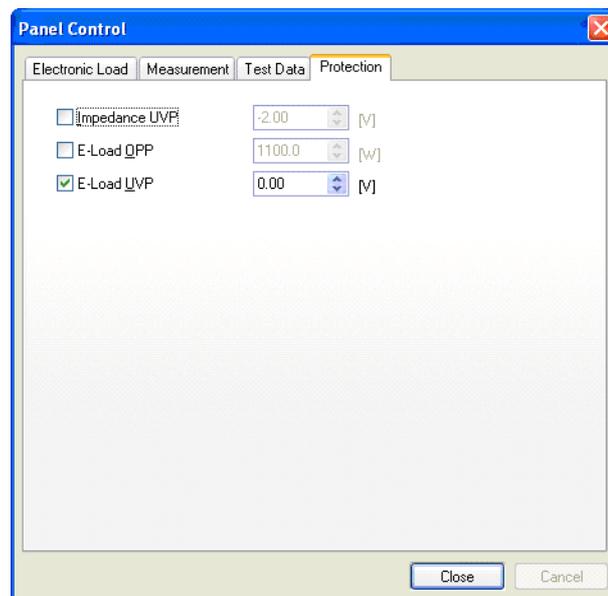
Fig.5-26   Protection page

5.5 Setting the Graph Display

You can set the graph display even while a test is in progress. The display items include graph options, copy to clipboard, zoom, move, cursor, and default.

5.5.1 Graph Options

From the **Graph** menu, select **Graph Options**. Scale, Pattern, View, and 3D pages appear.

Scale

For the scale, you can select **Manual**, **Auto**, or **Fixed**.

If you select manual scale, you can arbitrarily set the maximum and minimum values of the scale. If you select auto scale, the scale is automatically set from the measured data. If you select fixed scale, fixed scale values are set from the test conditions. This setting is available for time, voltage, and current (density). The fixed scale set from the test conditions is indicated in Table 5-4.
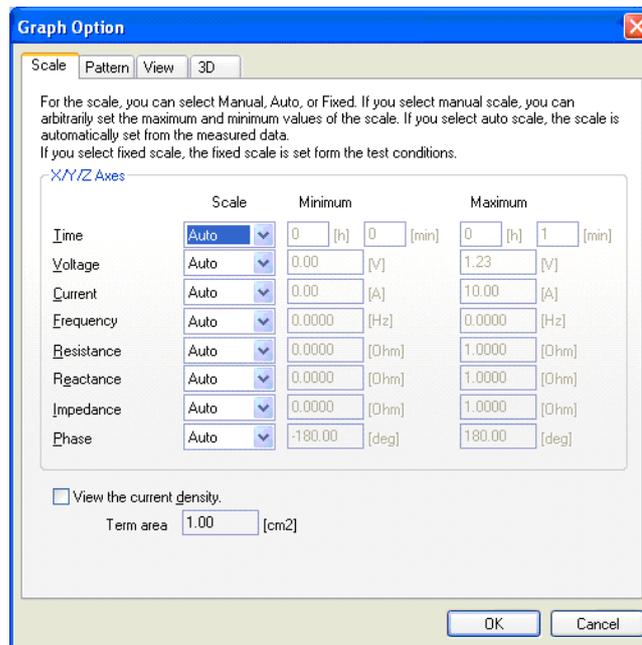
Fig.5-27 Scale page example

Table 5-4   Fixed scale set from the test conditions

Scale	Minimum value	Maximum value
Time	0 s	Generating time and rest time
Voltage	Impedance meter UVP	Nominal voltage
Current	0 A (the minimum current for I-V)	Current (the maximum current for I-V)
Frequency	The frequency specified here or the stop frequency, whichever is smaller.	The frequency specified here or the stop frequency, whichever is greater.

If you select the **View the current density** check box, the current density is calculated from the electrode area that is specified in the Fuel Cell Information of the test conditions. If the test conditions file is not loaded in the FCTester Executive, the electrode area is set to 1.00 [cm^2].

Pattern

You can set the color and width of the Y-axis line and the marker style and color. You can also set the color of the graph grid lines and the graph/frame background.
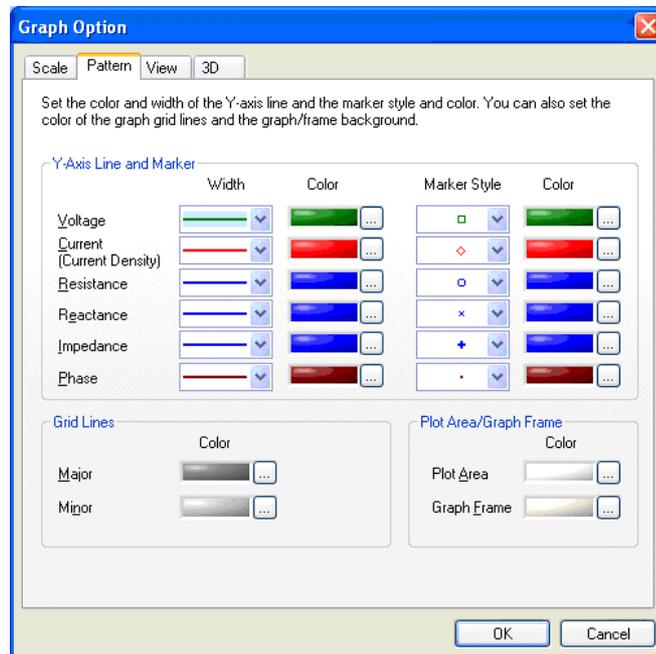
Fig.5-28   Pattern page example

View

Set the display format of the graph.
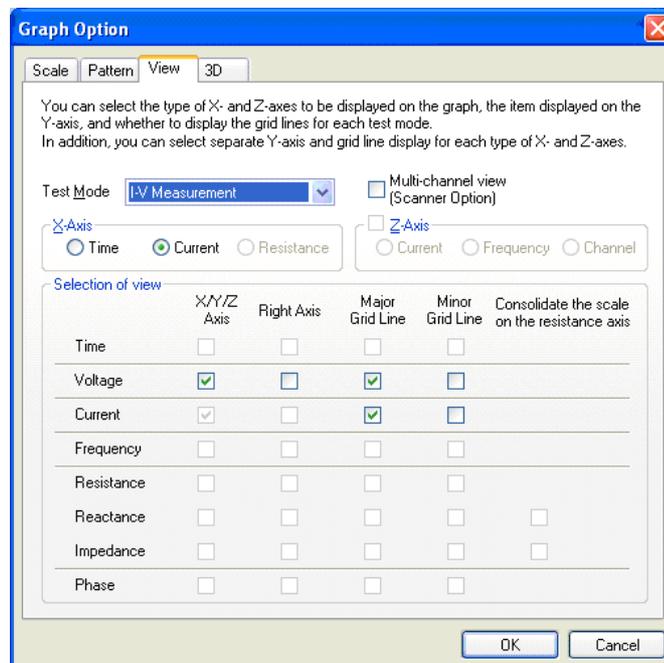
Fig.5-29   View page example

Select the X- and Z-axes type for each test mode. You can select the item to be assigned to the Y-axis, and turn on/off the scale line of each axis.

- You can select the Z-axis type depending on the test mode. Test modes on which the Z-axis is selected are displayed using a 3D graph. For 3D graphs, you can only select one item to be displayed on the Y-axis.

- Selecting the multi-channel view

  You can select the multi-channel view if the scanner option is being used. If you select the multi-channel view, select the X-axis type and the item displayed on the Y-axis. The Z-axis type is fixed to channel.

- Consolidate the scale on the resistance axis

  If you select this check box, the resistance and reactance are displayed consolidated on the resistance axis. The scale and pattern items of the resistance axis are used.

Table 5-5   Default display format

Test mode	X-axis type	Display selection
I-V measurement	Current	Voltage
V-I measurement	Current	Voltage
I-V + AC impedance measurement	Current	Voltage, resistance, or reactance
I-V + Cole-Cole plot measurement	Resistance	Reactance
Cole-Cole plot measurement	Resistance	Reactance
AC impedance measurement	Time	Voltage, current, resistance, or reactance
Current interrupt measurement	Time	Voltage, current, or resistance
Constant current test	Time	Voltage or current
Constant voltage test	Time	Voltage or current

3D

Sets the drawing method of the 3D graph. The setting becomes the default value of the 3D graph display.
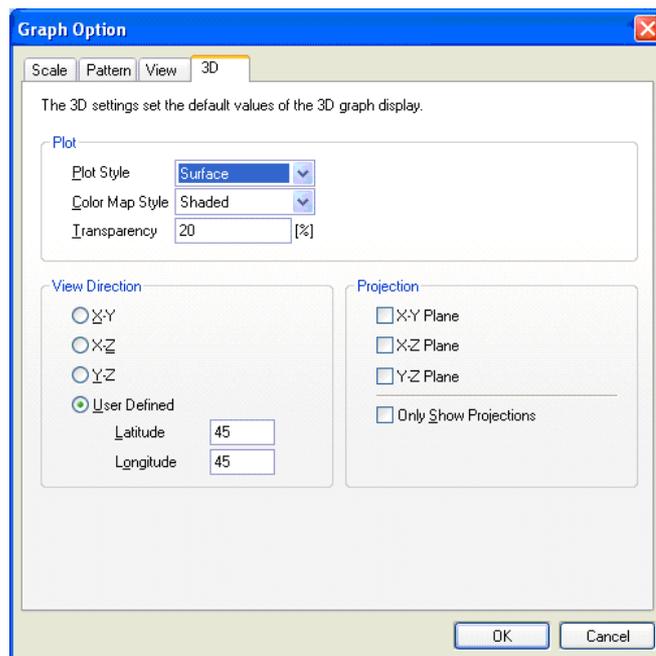
Fig.5-30   3D display page example

■ Plot

Plot Style	Drawing method
Point	Point
Line	Line
Line + Point	Lines and points
Hidden line	Hides lines that are located in places where they cannot be seen.
Contour	Contour
Surface	Surfaces
Surface + Line	Lines and surfaces
Surface + Contour	Contours and surfaces
Surface + Normal	Vector space and surfaces
Color Map Style	Drawing method
Shaded	Shaded
Color Spectrum	Rainbow
Gray Scale	Grayscale
Transparency	Drawing method
0 % to 100 %	Transparency
View direction	Drawing method
X-Y	X-Y, two dimensional
X-Z	X-Z, two dimensional
Y-Z	Y-Z, two dimensional
User Defined	X-Y-Z, three dimensional Latitude: Viewing angle (pitch angle) Longitude: Rotation angle (yaw angle)
Projection	Drawing method
X-Y Plane	X-Y surface
X-Z Plane	X-Z surface
Y-Z Plane	Y-Z surface
Only Show Projections	Displays only the projection surface

5.5.2 Zoom, Pan, and Cursor of the Graph

■ **Zoom function**

• 2D graph

From the **Graph** menu, select **Zoom** to expand the graph. Click the start point on the graph you want to zoom and drag the mouse to the end point.

The area shown with a dotted frame is expanded.

Click the start point you want to zoom and drag the mouse to the end point.

Fig.5-31 Zoom window of the 2D graph

• 3D graph

Hold down the Alt key and left-click on the graph. Then, drag the mouse up or down to expand or reduce the graph.

You can also scroll the mouse wheel to expand or reduce the graph.
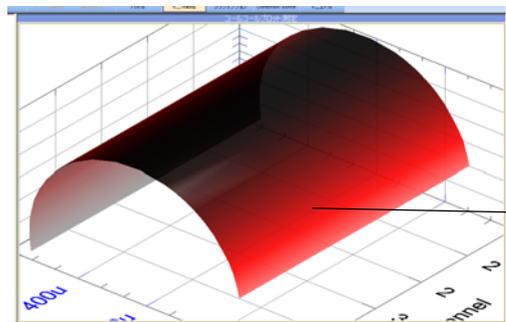
Hold down the Alt key and left-click on the graph. Then, drag the mouse up or down.

Fig.5-32 Zoom window of the 3D graph

■ **Pan**

• 2D graph

From the **Graph** menu, select **Pan** to move the graph.

Click on the graph and drag the mouse to move the graph.
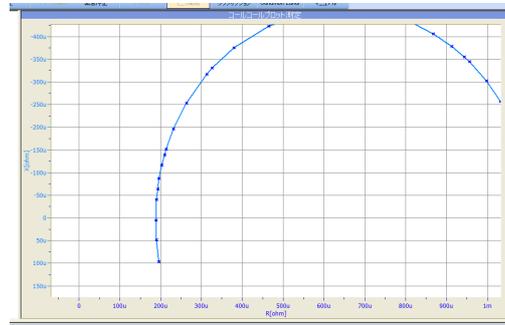
Click on the graph and drag the graph to the desired position.

Fig.5-33   Panned window of the 2D graph

• 3D graph

Hold down the Shift key and left-click on the graph. Then, drag the mouse to move the graph.
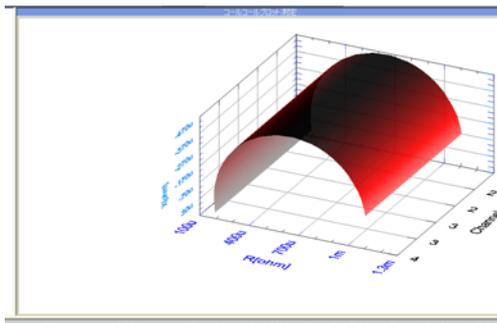
Hold down the Shift key and left-click on the graph. Then, drag the graph to the desired position.

Fig.5-34   Panned window of the 3D graph

■ Cursor

- 2D graph

  From the **Graph** menu, select **Cursor** to display a cursor. Drag the cursor to display the value at the point as a tool tip.

  Currently, this function is not supported on the 3D graph.
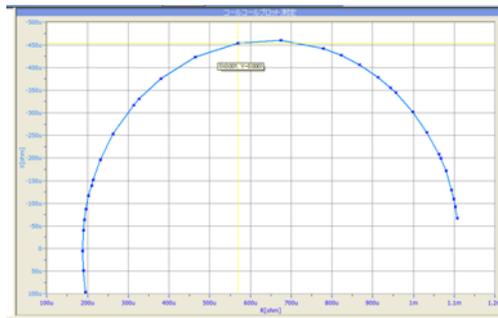
Drag the cursor to display the value at the point as a tool tip.

Fig.5-35　Cursor window of the 2D graph

■ Rotate

- 3D graph

  Click on the graph and drag the mouse to rotate the graph.
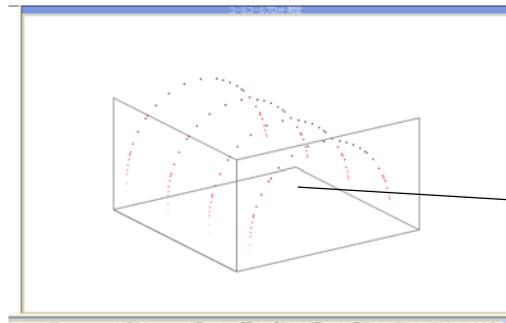
Left-click on the graph and drag the mouse up, down, right, or left.

Fig.5-36　Rotated window of the 3D graph

5.6   Test Data Files

A test data file is created each time a sequence is completed. A test data file is created even if you abort the test using Emergency Stop or Stop for the data up to that point.

The test data files are created in the same location with the test conditions file (.fcct extension), and the file names are assigned as follows:

(Example) When the test conditions file name is TEST1
Data file of a sequence
TEST1_I-V_1(2(1))_05Jan25_131834.CSV

- Extension
- Time (hour, minute, and second)
- Date (year, month, and day)
- Repeat count of the sequence
- Sequence number
- Repeat count of the cycle
- Test mode
- Test conditions file name
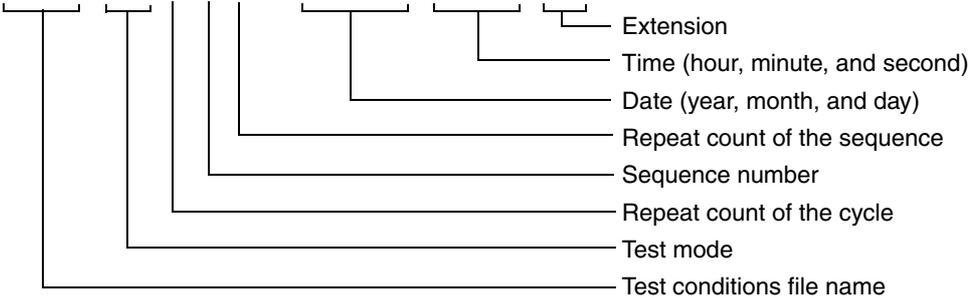
Data file of the startup sequence
TEST1_Start-up_05Jan25_131830.CSV

Data file of the shutdown sequence
TEST1_Shutdown_05Jan25_131844.CSV

NOTE
- Up to 4096 test data values are saved. Data values exceeding this number are deleted in order from the oldest value.

5

Executing Tests

5.6.1　File Description

The following is an example of a sequence data file opened with Excel or other spreadsheet application. The file consists of two parts: test condition data created with Condition Editor and test result data.

-Fuel Cell Information-			
Sample Name	sample1		
Membrane	ABC		
Catalyst	Pt-sample		
W/H/D	30	5	30
Weight [kg]	0.1		
Electrode Area [cm2]	4		
Nominal Voltage [V]	1.2		
Memo	sample1 TEST		

Fuel Cell Information

-Protection-		
Impedance UVP [V]/Mask Time [s]	-2	4
E-Load UVP [V]	0	
E-Load OPP [W]	300	

Protection

-Test condition-		
Test Mode	Cole Cole Plot	
Comment		
Measure OCV/Load Off Period [s]	Enable	2
Current Range [A]	132	
Current [A]	1	
Rest time [h:min:s]	0:0:0	
Start Frequency [Hz]	20000	
Stop Frequency [Hz]	100	
Measuring AC Current [%]	10	
Measure Range	AUTO	
Moving Average	32	
Cutoff Voltage [V]	0	

Test condition

-Result-	
Cycle	1 (2-1)
Termination Factor	Test End
Elapsed Time	0:1:25
OCV [V]	5.1632
Start Time	25/07/2018 16:59:12
Finish Time	25/07/2018 17:00:38
Start Voltage [V]	4.6788
Start Current [A]	1.1403
Start Resistance [m Ohm]	352.5087

Result

Start Reactance [m Ohm]: -14.3541
Start Impedance [m Ohm]: 352.8008
Start Phase [deg]: -2.33
Finish Voltage [V]: 4.7627
Finish Current [A]: 1.0008
Finish Resistance [m Ohm]: 584.2146
Finish Reactance [m Ohm]: -96.1729
Finish Impedance [m Ohm]: 592.0776
Finish Phase [deg]: -9.35

Time1 [h:min:s]	Voltage [V]	Current [A]	Time2 [h:min:s]	Frequency [Hz]	Resistance [m Ohm]	Reactance [m Ohm]	Impedance [m Ohm]	Phase [deg]	Cycle Voltage [V]	Cycle Current [A]
0:00:00	4.6691	1.1624	0:00:02	20000	352.5087	-14.3541	352.8008	-2.33	4.6865	1.1219
0:00:02	4.6814	1.1324	0:00:04	15800	350.371	-7.3746	350.4486	-1.21	4.6877	1.1224
0:00:04	4.6727	1.1422	0:00:06	12600	350.6058	-6.4502	350.6651	-1.05	4.6856	1.1232
0:00:06	4.6737	1.1762	0:00:09	10000	352.4903	-6.811	352.5561	-1.11	4.6849	1.1227
0:00:09	4.6912	1.1597	0:00:11	9000	354.4401	-4.9448	354.4746	-0.8	4.6853	1.1226
0:00:11	4.6531	1.2066	0:00:13	8000	353.918	-5.5286	353.9611	-0.89	4.6866	1.1223
0:00:13	4.6627	1.168	0:00:15	7000	353.9027	-3.83	353.9234	-0.62	4.6862	1.1234
0:00:15	4.65	1.1742	0:00:18	6300	355.2192	-3.1122	355.2329	-0.5	4.6865	1.1219
0:00:18	4.6811	1.1235	0:00:20	6000	356.2516	-3.1987	356.2659	-0.51	4.6849	1.1235
0:00:20	4.6975	1.1079	0:00:22	5000	355.193	-0.8921	355.1941	-0.14	4.6855	1.1228
0:00:22	4.66	1.1754	0:00:24	4000	352.6647	2.0959	352.671	0.34	4.6855	1.1236
0:00:25	4.66	1.1793	0:00:27	3160	345.2523	2.3007	345.26	0.38	4.6864	1.1233
0:00:27	4.6825	1.1371	0:00:29	3000	343.639	1.3415	343.6416	0.22	4.686	1.1234
0:00:29	4.6323	1.266	0:00:32	2510	337.2833	-3.784	337.3045	-0.64	4.6855	1.1227
0:00:31	4.6591	1.2087	0:00:34	2000	332.069	-14.457	332.3836	-2.49	4.6856	1.122
0:00:33	4.7266	1.0088	0:00:37	1580	330.0544	-27.4793	331.1964	-4.76	4.6864	1.1225
0:00:36	4.6972	1.0972	0:00:40	1260	331.9672	-42.9418	334.733	-7.37	4.6874	1.1221
0:00:38	4.7116	1.0359	0:00:43	1000	337.092	-59.9793	342.3865	-10.09	4.6858	1.1223
0:00:40	4.7253	0.9768	0:00:47	900	340.7608	-66.683	347.2241	-11.07	4.6845	1.1231
0:00:42	4.6446	1.2561	0:00:50	800	345.7149	-76.6721	354.1149	-12.5	4.6862	1.1223
0:00:45	4.7076	1.0559	0:00:54	700	352.6788	-85.1012	362.801	-13.57	4.6849	1.1228
0:00:47	4.689	1.1196	0:00:58	630	359.4185	-95.1058	371.7886	-14.82	4.6844	1.123
0:00:49	4.6436	1.2656	0:01:01	600	363.7203	-97.5474	376.5739	-15.01	4.6841	1.1231
0:00:51	4.7127	0.9919	0:01:05	500	377.9028	-111.915	394.1262	-16.5	4.6843	1.1227
0:00:54	4.6248	1.2707	0:01:08	400	402.4252	-130.113	422.9367	-17.92	4.6845	1.1225
0:00:56	4.6651	1.093	0:01:10	316	431.9798	-142.499	454.8764	-18.26	4.6844	1.1227
0:00:58	4.708	1.0187	0:01:12	300	440.8685	-144.92	464.0762	-18.2	4.6846	1.1223
0:01:00	4.7396	0.9959	0:01:15	251	465.2571	-148.555	488.3983	-17.71	4.6851	1.1213
0:01:03	4.7083	1.0259	0:01:17	200	503.8861	-150.795	525.9662	-16.66	4.6844	1.1228
0:01:05	4.6233	1.2534	0:01:20	158	536.5321	-139.067	554.2619	-14.53	4.6852	1.1217
0:01:07	4.6622	1.2221	0:01:22	126	567.5908	-123.806	580.9366	-12.3	4.6849	1.1225
0:01:09	4.7334	1.004	0:01:25	100	584.2146	-96.1729	592.0776	-9.35	4.6851	1.1227
0:01:12	4.6141	1.2346								
0:01:14	4.6521	1.2104								
0:01:16	4.7533	1.0048								
0:01:18	4.7559	0.9719								
0:01:21	4.7331	1.0192								
0:01:23	4.668	1.1045								
0:01:25	4.5964	1.2699								

Description of each part

-Fuel Cell Information-

Sample Name	sample1
Membrane	ABC
Catalyst	Pt-sample
W/H/D	30 5 30
Weight [kg]	0.1
Electrode Area [cm2]	4
Nominal Voltage [V]	1.2
Memo	sample1 TEST

The information entered from the screen on the right is recorded.
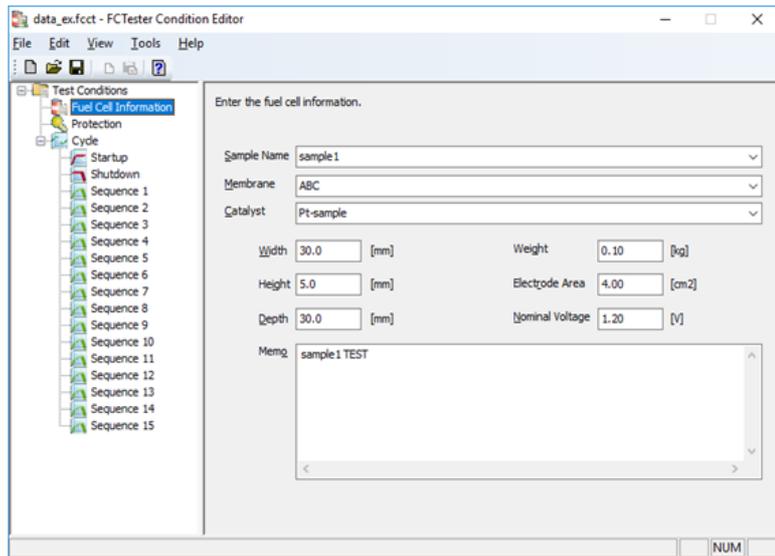
-Protection-

Impedance UVP [V]/ Mask Time [s]	-2 4
E-Load UVP [V]	0
E-Load OPP [W]	300

The information entered from the screen on the right is recorded.

-Test condition-

Test Mode	Cole Cole Plot
Comment	
Measure OCV/Load Off Period [s]	Enable 2
Current Range [A]	132
Current [A]	1
Rest time [h:min:s]	0:0:0
Start Frequency [Hz]	20000
Stop Frequency [Hz]	100
Measuring AC Current [%]	10
Measure Range	AUTO
Moving Average	32
Cutoff Voltage [V]	0

The information entered from the screen on the right is recorded.
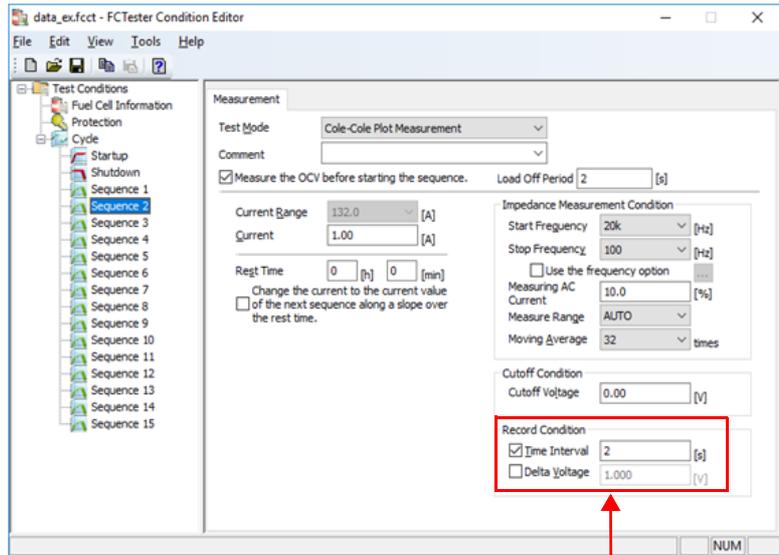
The "Time1" voltage and current indicated on the next page are recorded using these conditions.

-Result-

Cycle	1 (2-1)
Termination Factor	Test End
Elapsed Time	0:1:25
OCV [V]	5.1632
Start Time	25/07/2018 16:59:12
Finish Time	25/07/2018 17:00:38
Start Voltage [V]	4.6788
Start Current [A]	1.1403
Start Resistance [m Ohm]	352.5087
Start Reactance [m Ohm]	-14.3541
Start Impedance [m Ohm]	352.8008
Start Phase [deg]	-2.33
Finish Voltage [V]	4.7627
Finish Current [A]	1.0008
Finish Resistance [m Ohm]	584.2146
Finish Reactance [m Ohm]	-96.1729
Finish Impedance [m Ohm]	592.0776
Finish Phase [deg]	-9.35

The measurement results at the start and end of the test are recorded.
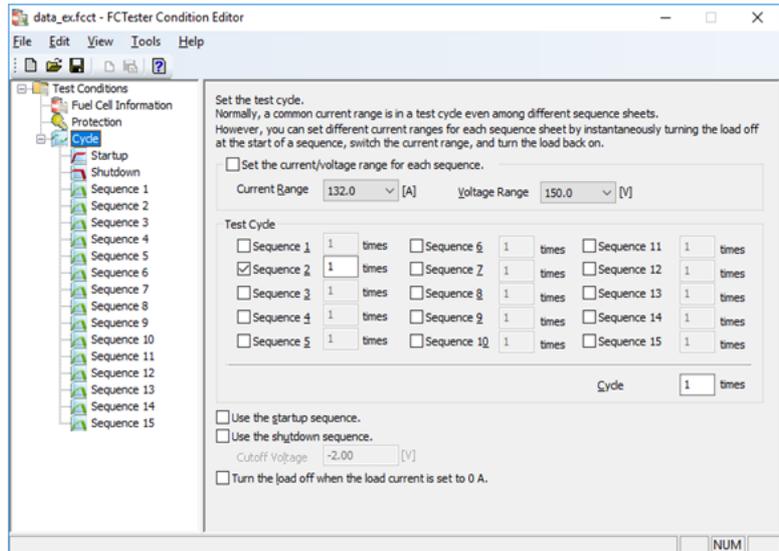
Time1: The amount of time that has elapsed since the test started when voltage and current are recorded according to the recording conditions on the sequence screen. The condition in this example is 2 second time interval.

Time2: The amount of time that has elapsed since the test started when the impedance measurement results of each frequency are recorded.

Time1 [h:min:s]	Instantaneous value		Time2 [h:min:s]	Frequency [Hz]	Impedance measurement result				Average voltage and average current per cycle	
	Voltage [V]	Current [A]			Resistance [m Ohm]	Reactance [m Ohm]	Impedance [m Ohm]	Phase [deg]	Cycle Voltage [V]	Cycle Current [A]
0:00:00	4.6691	1.1624	0:00:02	20000	352.5087	-14.3541	352.8008	-2.33	4.6865	1.1219
0:00:02	4.6814	1.1324	0:00:04	15800	350.371	-7.3746	350.4486	-1.21	4.6877	1.1224
0:00:04	4.6727	1.1422	0:00:06	12600	350.6058	-6.4502	350.6651	-1.05	4.6856	1.1232
0:00:06	4.6737	1.1762	0:00:09	10000	352.4903	-6.811	352.5561	-1.11	4.6849	1.1227
0:00:09	4.6912	1.1597	0:00:11	9000	354.4401	-4.9448	354.4746	-0.8	4.6853	1.1226
0:00:11	4.6531	1.2066	0:00:13	8000	353.918	-5.5286	353.9611	-0.89	4.6866	1.1223
0:00:13	4.6627	1.168	0:00:15	7000	353.9027	-3.83	353.9234	-0.62	4.6862	1.1234
0:00:15	4.65	1.1742	0:00:18	6300	355.2192	-3.1122	355.2329	-0.5	4.6865	1.1219
0:00:18	4.6811	1.1235	0:00:20	6000	356.2516	-3.1987	356.2659	-0.51	4.6849	1.1235
0:00:20	4.6975	1.1079	0:00:22	5000	355.193	-0.8921	355.1941	-0.14	4.6855	1.1228
0:00:22	4.66	1.1754	0:00:24	4000	352.6647	2.0959	352.671	0.34	4.6855	1.1236
0:00:25	4.66	1.1793	0:00:27	3160	345.2523	2.3007	345.26	0.38	4.6864	1.1233
0:00:27	4.6825	1.1371	0:00:29	3000	343.639	1.3415	343.6416	0.22	4.686	1.1234
0:00:29	4.6323	1.266	0:00:32	2510	337.2833	-3.784	337.3045	-0.64	4.6855	1.1227
0:00:31	4.6591	1.2087	0:00:34	2000	332.069	-14.457	332.3836	-2.49	4.6856	1.122
0:00:33	4.7266	1.0088	0:00:37	1580	330.0544	-27.4793	331.1964	-4.76	4.6864	1.1225
0:00:36	4.6972	1.0972	0:00:40	1260	331.9672	-42.9418	334.733	-7.37	4.6874	1.1221
0:00:38	4.7116	1.0359	0:00:43	1000	337.092	-59.9793	342.3865	-10.09	4.6858	1.1223
0:00:40	4.7253	0.9768	0:00:47	900	340.7608	-66.683	347.2241	-11.07	4.6845	1.1231
0:00:42	4.6446	1.2561	0:00:50	800	345.7149	-76.6721	354.1149	-12.5	4.6862	1.1223
0:00:45	4.7076	1.0559	0:00:54	700	352.6788	-85.1012	362.801	-13.57	4.6849	1.1228
0:00:47	4.689	1.1196	0:00:58	630	359.4185	-95.1058	371.7886	-14.82	4.6844	1.123
0:00:49	4.6436	1.2656	0:01:01	600	363.7203	-97.5474	376.5739	-15.01	4.6841	1.1231
0:00:51	4.7127	0.9919	0:01:05	500	377.9028	-111.915	394.1262	-16.5	4.6843	1.1227
0:00:54	4.6248	1.2707	0:01:08	400	402.4252	-130.113	422.9367	-17.92	4.6845	1.1225
0:00:56	4.6651	1.093	0:01:10	316	431.9798	-142.499	454.8764	-18.26	4.6844	1.1227
0:00:58	4.708	1.0187	0:01:12	300	440.8685	-144.92	464.0762	-18.2	4.6846	1.1223
0:01:00	4.7396	0.9959	0:01:15	251	465.2571	-148.555	488.3983	-17.71	4.6851	1.1213
0:01:03	4.7083	1.0259	0:01:17	200	503.8861	-150.795	525.9662	-16.66	4.6844	1.1228
0:01:05	4.6233	1.2534	0:01:20	158	536.5321	-139.067	554.2619	-14.53	4.6852	1.1217
0:01:07	4.6622	1.2221	0:01:22	126	567.5908	-123.806	580.9366	-12.3	4.6849	1.1225
0:01:09	4.7334	1.004	0:01:25	100	584.2146	-96.1729	592.0776	-9.35	4.6851	1.1227
0:01:12	4.6141	1.2346								
0:01:14	4.6521	1.2104								
0:01:16	4.7533	1.0048								
0:01:18	4.7559	0.9719								
0:01:21	4.7331	1.0192								
0:01:23	4.668	1.1045								
0:01:25	4.5964	1.2699								

Time1 and Time2 are the amount of time elapsed from the start of a single test. They are not recorded as times of separate tests.
Taking the times enclosed in frames as an example, the voltage and current values are recorded at 0:01:14 according to the 2 second time interval. Next, an impedance measurement at 251 Hz is completed and the measured value is recorded at 0:01:15. Then, the voltage and current values are recorded again at 0:01:16 according to the 2 second time interval.

NOTE

- The voltage and current at Time1 are instantaneous values. When values are to be recorded according to the recording conditions, if the relevant values are in the middle of a measurement, the values may appear as blanks.

- The FCTester uses the PC clock. Even when the recording condition is set to Time Interval, the specified time interval may not be achieved depending on the performance of the PC or other running applications. Errors accumulate.

- If you set the recording condition to Delta Voltage, values will be recorded whenever there is a voltage change, so the time interval will not be inconsistent.

5.7   A List of Menus

Menu		Description
File	Open	Opens the test conditions file created using the Condition Editor.
	Exit	Closes the application. You cannot close the application while the test is in progress.
View	Toolbar	Shows or hides the toolbar.
		Shows or hides the status monitor.
	Status Bar	Shows or hides the status bar.
Test	Start	Starts the test. If the startup sequence is enabled, the load is automatically turned on. If the startup sequence is disabled, you must turn the load on before starting the test.
	Stop	Stops the test. Select an item in the dialog box.
	Reset Alarm	Resets the alarm when an alarm occurs.
	Emergency Stop	Stops the test, and turns off the load of the electronic load unit.
	Panel Control	Allows you to carry out operations equivalent to the operations on the KFM2150. Set items in the dialog box. The dialog box consists of the Electronic Load, Measurement, Test Data, and Protection pages.
	Monitor	Start the voltage/current monitor. You must start the monitor to start the test.
Graph	Graph Options	Set the graph scale, pattern, view, and 3D items.
	Copy to Clipboard	Copies the graph to the clipboard.
	Zoom	Zooms the graph.
	Pan	Moves the graph.
	Cursor	Shows the cursor.
	Default	Sets the graph functions back to default.
Tools	Start the Condition Editor	Starts the Condition Editor. This is used to set test conditions.
	Options	This is used to change the test conditions during the test.
Help	View the FCTester User's Manual	Shows the FCTester User's Manual.
	About	Shows the FCTester version and the system information while executing the Configuration Tool.

5

Executing Tests