User's Manual

Engine Combustion Pressure Analysis (707765) Monitor Function of Engine Combustion Pressure (707768) (For Gas)

YOKOGAWA

Yokogawa Meters & Instruments Corporation

IM 707765-61E
1st Edition

Introduction

Thank you for purchasing the Engine Combustion Pressure Analysis.
This user's manual contains useful information about the functions and operating procedures of the software. To ensure proper use of the software, please read this manual thoroughly before beginning operation. After reading the manual, keep it in a convenient location for quick reference in the event a question arises.
This software loads files (.hdr and .wvf files) containing engine combustion pressure data that was measured by the DL708E, DL716, DL750, or WE7000 and performs analysis. The analysis results can be saved in CSV format and easily opened by a spreadsheet program such as Microsoft Excel. The type of engines that can be analyzed differ depending on the measuring instrument as follows:

DL708E:	Max. 6 cylinders
DL716, DL750, WE7000:	Max. 8 cylinders

Note

- This manual applies to version 4 of the Engine Combustion Pressure Analysis or Monitor Function of Engine Combustion Pressure.
- The contents of this manual are subject to change without prior notice as a result of improvements in the software's performance and functions. Display contents illustrated in this manual may differ slightly from what actually appears on your screen.
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Overview of This Manual

This manual consists of seven chapters and an appendix as described below.

Chapter	Title	Description
1	System Configuration	Describes the various hardware and software configurations needed for different applications of the software.
2	Overview	Provides an overview of software functions as well as an explanation of the software setup procedure, the directory structure, and the software screens.
3	Screens and Operations	Gives descriptions of the various screens included in the software, and how they are used.
4	CSV Files	Provides a list of items that can be saved to .csv files.
5	Equations	Explains how each item is calculated.
6	Monitor Function (Add-On)	Gives an overview of the monitor function and how to set it up, and provides an explanation of the various software screens associated with the monitor function and how to operate them.
7	Error Messages	Provides a list of error messages.
Appendix		Explains how to set up the WE7000 and DL750.
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Conventions Used in This Manual

- The following symbols and codes are used in the tables that describe the software's settings and display data.
  - Data Type
    C : Character string
    I : Integer
    F : Floating point
  - Size
    For numerical data
    10.2
    Number of digits displayed before the decimal point (no. of bytes)
    Total number of characters displayed (including the decimal point, +/– signs, e and E)(no. of bytes)

    For character strings
    38
    Maximum number of bytes
- When necessary for clarity, key names of the measuring instrument and items that appear on screen are set in boldface.

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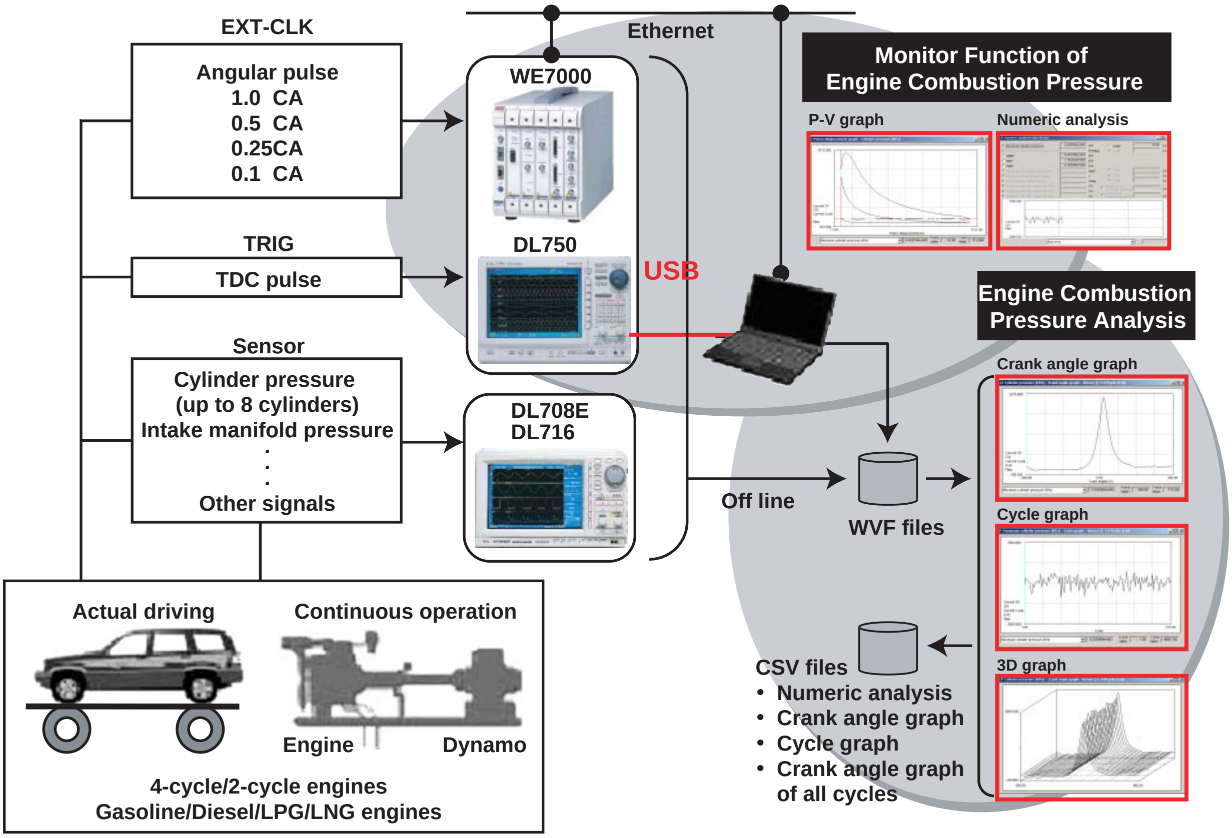
1.1 Hardware Configuration

You can set the TDC pulse as the trigger, then synchronize the engine cylinder pressure and other signals to the angular pulse and perform measurement.



- **PC System Requirements**

  OS: Windows XP, Windows 2000 Pro, Windows NT 4.0, Windows 98
  However, Windows NT 4.0 is not supported when using USB.
  CPU: Pentium III, 1 GHz or higher
  Memory: 256 MB or more
  Hard disk: 2 GB or more of free space

- **For the DL708E/DL716**
  - Main Unit
    DL708E or DL716 (with internal hard disk)
    Memory length > (no. of analyzed cycles + 3) × 1 cycle data length
    For 4-cycle engines: 1 cycle data length = (360/res) × 2
    For 2-cycle engines: 1 cycle data length = (360/res)
  - Measurement module
    701852/701853
    However, ((RPM/60) × 360/res) < 100 kHz
    res : angular resolution (1, 0.5, 0.25, 0.1)

- **For the DL750**
  - Main Unit
    DL750 (with a Zip drive, PC card slot, or internal hard disk)
    Memory length > (no. of analyzed cycles + 3) × 1 cycle data length
    For 4-cycle engines: 1 cycle data length = (360/res) × 2
    For 2-cycle engines: 1 cycle data length = (360/res)
  - Measurement module
    701251
    However, ((RPM/60) × 360/res) < 1 MHz
    res : angular resolution (1, 0.5, 0.25, 0.1)

- **For the WE7000**
  - Main Unit
    WE800 or WE400 (1 unit)
  - Communications I/F
    WE7035/WE7036, WE7037/WE7038, or WE7052
  - Measurement module
    WE7235, WE7245, WE7271/WE7272
    However, ((RPM/60) × 360/res) < 100 kHz
    WE7275
    However, ((RPM/60) × 360/res) < 1 MHz
    res : angular resolution (1, 0.5, 0.25, 0.1)

1.2 Software Configuration

Engine Combustion Pressure Analysis

- **Loading Measurement Data**
  You can load saved .wvf files (Yokogawa's proprietary format) containing cylinder pressure data from a 4-cycle or 2-cycle engine measured on the DL708E, DL750, or WE7000.
  A portion of this data (up to 800 cycles worth) can be extracted for filter processing, rotational offset correction, or TDC correction, then analyzed.
  By running the Monitor Function of the Engine Combustion Pressure Analysis Package, you can analyze previously saved WVF files at the same time.

- **Loading and Saving Analysis Conditions**
  You can save and load analysis conditions (TDC correction value, interval of absolute pressure correction, analysis parameters, calculation data items, display window layout, and graph display conditions). The analysis conditions from the previous session are automatically loaded upon start-up.

- **Filter Processing**
  You can shape the waveform by applying filters (None, Lowpass, Bandpass, Highpass) to motoring and firing pressure data, then perform rotational offset correction, TDC correction, and combustion pressure analysis calculations.

- **TDC Correction**
  Using motoring data, you can determine the offset between the TDC pulse position and the actual TDC position, then perform analysis. Or, you can enter the offset value manually.

- **Absolute Pressure Correction, Physical Value Conversion, and other Signals**
  You can assign channels to measurement signals. You can assign channels 1 through 16 to cylinder pressure (up to 8 cylinders), intake manifold pressure, intake manifold temperature, fuel consumption, rpm, and other signals. Also, you can specify the coefficients for conversion to physical values (calibration factors, A and B in $y=Ax+B$). Cylinder pressure is corrected to absolute pressure.

- **Combustion Pressure Analysis/Results Display**
  - You can select multiple combustion pressure analysis items or input them manually, then perform combustion pressure analysis.
  - After the analysis, you can select computed items one at a time for graphical or numerical display.
  - New manually input items and analysis items can be entered or selected so that additional calculations can be performed.

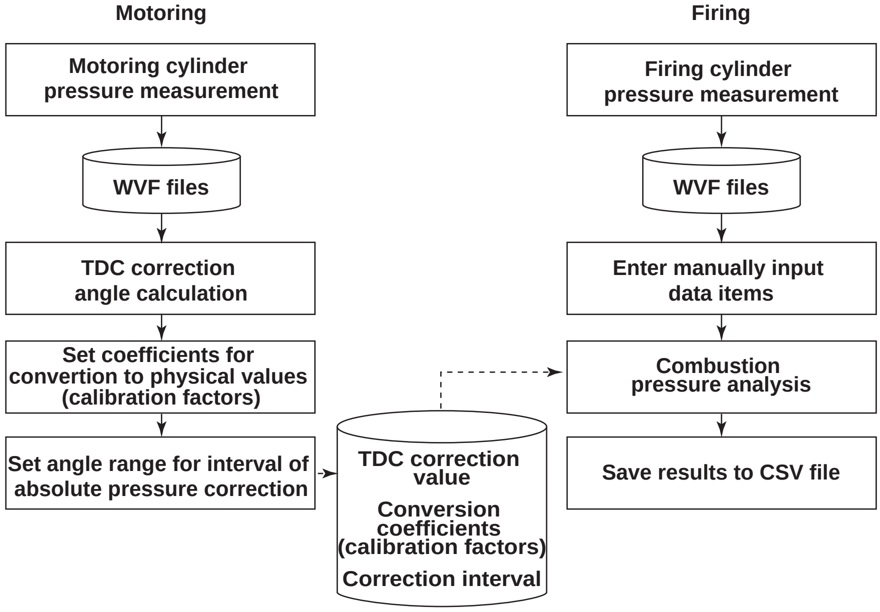
- **Saving Analysis Data in CSV Format**
  You can save test information (settings at time data was saved), manually input items, and calculated analysis results data in CSV format.

Monitor Function of Engine Combustion Pressure

The Monitor Function of Engine Combustion Pressure (hereinafter, the Monitor Function) is an add-on for the Engine Combustion Pressure Analysis.
This function is only available when used in conjunction with the Engine Combustion Pressure Analysis.
With the Monitor function, you can use your WE7000 series instrument (WE7235, WE7245, WE7271, WE7272, or WE7275) or the DL750 to measure cylinder pressure over given periods of time during motoring or firing, and continuously monitor the measurements. You can also save the resultant data. For details, see chapter 6.

2.1 Overview of Functions

Procedure



Loading Measurement Data

You can select a specific cycle range from the waveform data that was measured and saved by the DL708E, DL716, DL750, WE7000, and load that selected portion of the data into the software.

- Motoring data
  Data for TDC correction
- Firing data
  Data for combustion pressure analysis (signals coming from each channel, starting with CH1, in the firing order)
  - Number of cylinders: Up to 8 cylinders (or up to 6 cylinders for the DL708E)
  - No. of cycles: Up to 800 cycles
  - Angular resolution: 1, 0.5, 0.25, 0.1 CA

With this software, you cannot check whether or not the data meets the above conditions.

Filter Processing

You can apply filters to motoring data and firing data. When applying filters, the first cycle's worth of data is always dropped to cancel out the effect of signal rise. The remaining data is treated as the raw data, and used for rotational offset correction, TDC correction, and combustion pressure analysis.

- Filter types
  None, Lowpass, Bandpass, Highpass
- Characteristics
  4th order (24 db/oct) butterworth
- Cutoff frequency
  - At 1 CA resolution, 7.2 order (times) of the number of revolutions (2%) – 72 order (times) (20%)
  - At 0.5 CA resolution, 14.4 order (times) of the number of revolutions (2%) – 144 order (times) (20%)
  - At 0.25 CA resolution, 28.8 order (times) of the number of revolutions (2%) – 288 order (times) (20%)
  - At 0.1 CA resolution, 72 order (times) of the number of revolutions (2%) – 720 order (times) (20%)

  * The percentage in parentheses is the ratio relative to the sampling frequency.
  % = specified multiple / (360 degrees / angular resolution (1, 0.5, 0.25, 0.1)) × 100

  For example, to apply a low pass filter with a 1 kHz cutoff:
  At 3000 rpm (equivalent to 50 Hz),
  Cutoff = 1 kHz divided by 50 Hz = 20 times the rpm.

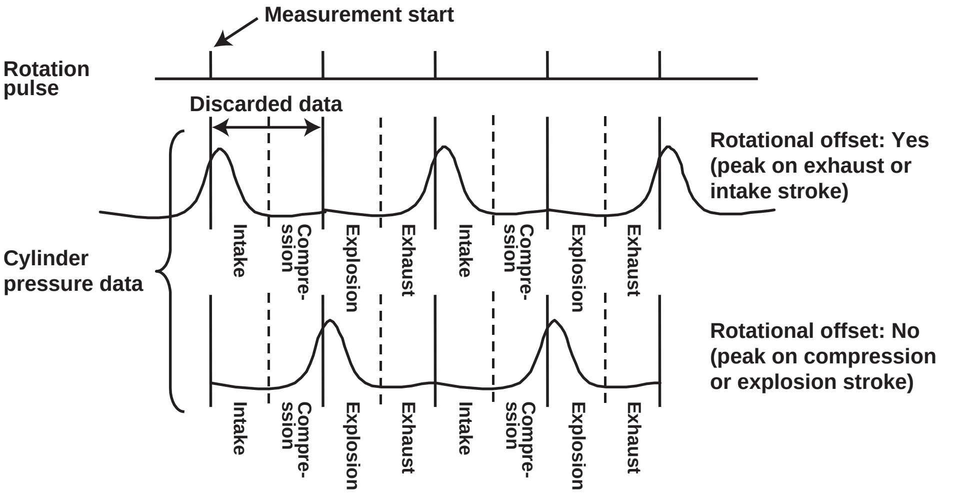
When this process is carried out, the TDC correction value is calculated using the filtered data, and all analyses are performed.

Measurement Data Review

To facilitate checking of measured data, the motoring and firing data are displayed in the crank angle graph.
If filters were applied, filtered waveforms are displayed.

Rotational Offset and TDC Correction (Calculated on Motoring Data)

Since rotation pulse (TDC) signals are output once per revolution, there is an offset of 1/2 cycle for each single cycle of intake, compression, explosion, and exhaust. Therefore, the crank angle at the maximum point of pressure is determined from within one cycle's worth of data, and if there is a pressure peak on the exhaust or intake stroke, the first 1/2 cycle's worth of data is discarded.

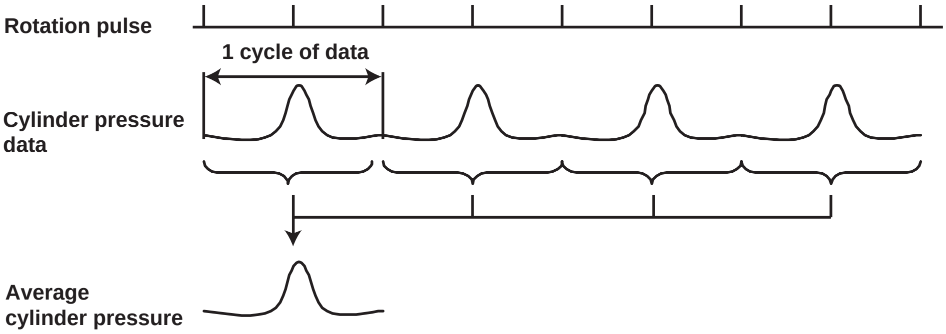


If the crank angle at the maximum point of pressure < −180 CA or if +180 CA < the crank angle at the maximum point of pressure, the rotational offset is set to "yes."

For the pressure data from the first cylinder during motoring, the software searches for the maximum pressure value after the rotational offset correction is performed, then determines the TDC position. It then calculates the offset from the TDC pulse position. This offset value is used for all analysis thereafter.

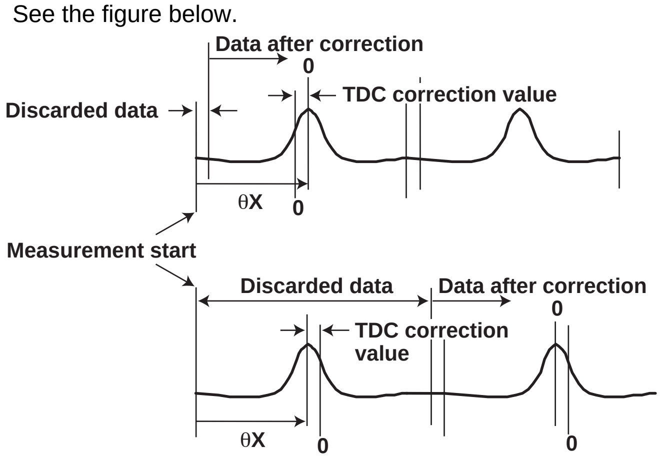
- **TDC Correction Calculation Method**

(1) You can compute the average data for all cycles of the cylinder pressure data from the motoring data of the first cylinder.



(2) Using 10 CA's worth of data before and after the maximum pressure point of the averaged cylinder pressure data, you can apply the least square method to compute the crank angle of maximum cylinder pressure θX.

(3) The TDC correction value can be determined using θX. The TDC correction value is given as the amount of divergence of the maximum pressure point θX from the start of measurement, and a correction value is determined such that the position of θX is zero (CA).
See the figure below.



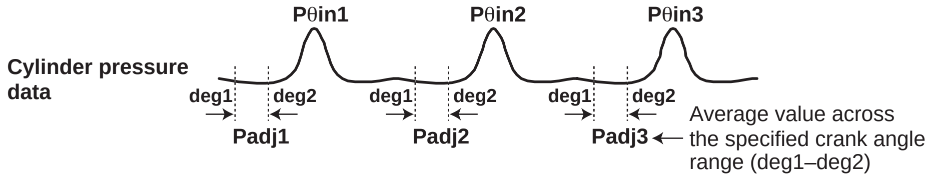
Absolute Pressure Correction

You can convert measured cylinder pressure to absolute cylinder pressure. For example, cylinder pressure can be corrected so that the average cylinder pressure (on a per cycle or all cycle basis) of the crank angle range near BDC (which can be specified by the user) equals the atmospheric or intake manifold pressure. You can manually input atmospheric pressure (including boost pressure) or use measured intake manifold pressure.

- **When using the per-cycle average value**

Pressure after absolute pressure correction = $P\theta in_n - Padj_n + Px_n$

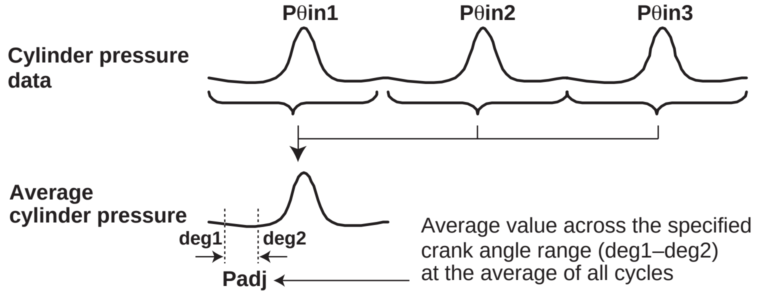
Px_n: Atomospheric pressure (including boost pressure) or intake manifold pressure



- **When using the all-cycle average value**

Pressure after absolute pressure correction = $P\theta in_n - Padj + Px_n$

Px_n: Atomospheric pressure (including boost pressure) or intake manifold pressure



Other Signals

You can specify signals that are not to be used for combustion pressure analysis. There are no physical units for the channels selected here. Please consider these values to have whatever units are appropriate for your application. When converting voltage to physical values, enter the conversion coefficients (calibration factors) A and B for the equation y=Ax+B. Also, note that absolute pressure correction is not performed on these signals.

During analysis, cycle-averaged values are displayed in the crank angle graph, the average value at each cycle is shown in the cycle graph, and the data can be saved in CSV format. TDC correction is based on the first cylinder.

Combustion Pressure Analysis/Results Display

Combustion pressure analysis can be performed after selecting combustion pressure analysis items and entering manual input items. After analysis, the analysis results for the selected items are graphically or numerically displayed.

- **Combustion Pressure Analysis Data Items**
  Crank Angle Graph
  - Cylinder pressure
  - Rate of cylinder pressure rise
  - Amount of heat release
  - Rate of heat release
  - Combustion mass rate
  - Cylinder gas temperature
  - Polytropic index
  - Raito of specific heat
  - Other signals

P-V Graph
- Cylinder pressure - Piston displacement graph
- Logarithmic cylinder pressure - Logarithmic piston displacement graph

Cycle Graph
- Maximum cylinder pressure
- Averaged maximum cylinder pressure of all cylinders
- Crank angle at maximum cylinder pressure
- Averaged crank angle at maximum cylinder pressure of all cylinders
- Maximum rate of pressure rise
- Averaged maximum rate of cylinder pressure rise of all cylinders
- Crank angle at maximum rate of cylinder pressure rise
- Averaged angle at maximum rate of cylinder pressure rise of all cylinders
- NMEP
- Averaged NMEP of all cylinders
- IMEP
- Averaged IMEP of all cylinders
- PMEP
- Averaged PMEP of all cylinders
- Maximum amount of heat release
- Crank angle at maximum amount of heat release
- Maximum rate of heat release
- Crank angle at maximum rate of heat release
- Crank angle at combustion mass rate N1 %
- Crank angle at combustion mass rate N2 %
- Crank angle at combustion mass rate N3 %
- Other signals

Analysis Data Items Graphed in 3D
- Cylinder pressure
- Rate of cylinder pressure rise
- Amount of heat release
- Rate of heat release
- Combustion mass rate
- Cylinder gas temperature
- Polytropic index
- Raito of specific heat
- Other signals

- **Numeric Analysis Data Items**
  - Average cylinder pressure across correction interval
    (When calculating the average pressure of the crank angle range determined from the all-cycle average and applying the result to all cycles)
  - Piston displacement
  - Average, standard deviation, and rate of change of the maximum cylinder pressure
  - Average, standard deviation, and rate of change of the maximum rate of cylinder pressure rise
  - Average, standard deviation, and rate of change of NMEP
  - Average, standard deviation, rate of change, minimum, and LNV of IMEP
  - Average, standard deviation, and rate of change of PMEP
  - Rate of misfire
  - Average, standard deviation, and rate of change of the maximum cylinder gas temperature
  - Average, standard deviation, and rate of change of the maximum rate of heat release

- Average, standard deviation, and rate of change of the maximum amount of heat release
- Average, standard deviation, and rate of change of the angle at combustion mass rate N1%
- Average, standard deviation, and rate of change of the angle at combustion mass rate N2%
- Average, standard deviation, and rate of change of the angle at combustion mass rate N3%
- Average start point of combustion (point a)
- Average end point of combustion (point b)
- Averaged maximum cylinder pressure of all cycles and cylinders
- Averaged maximum rate of cylinder pressure rise of all cycles and cylinders
- Averaged NMEP of all cycles and cylinders
- Averaged IMEP of all cycles and cylinders
- Averaged PMEP of all cycles and cylinders
- Minimum IMEP of all cycles and cylinders
- LNV of IMEP of all cycles and cylinders
- Oxygen requirement
- Exhaust gas volume
- Theoretical air
- Theoretical exhaust gas volume
- Amount of water produced
- Theoretical volume of dry exhaust gas
- Excess air factor
- Intake air volume
- Intake fuel-air mixture volume
- Volumetric efficiency
- Specific gravity of fuel gas
- Mass of intake air
- Mass of intake fuel
- Mass of intake gas mixture
- Gas mixture constant
- True heat release of gas fuel
- Cooling loss
- Cooling loss ratio
- Brake thermal efficiency
- Friction loss
- Combustion efficiency
- Degree of constant volume
- Indicated efficiency

- **Manually Input Data Items**
  - TDC correction values
  - Conversion coefficients (calibration factors A and B)
  - Unused channels
  - Starting angle of correction interval
  - Ending angle of correction interval
  - Con-rod length
  - Bore
  - Piston offset
  - Stroke length
  - Clearance volume

- Compression ratio
- Method of absolute pressure correction
- Number of data items for judging start point of combustion
- Number of data items for judging end point of combustion
- Starting angle of combustion
- Ending angle of combustion
- Search range of maximum rate of heat release
- Fuel consumption
- Atmospheric temperature
- Atmospheric pressure
- Revolutions per minute
- Boost pressure
- Engine power
- Number of cylinders
- Composition ratio of methane
- Composition ratio of ethane
- Composition ratio of propane
- Composition ratio of isobutane
- Composition ratio of n-butane
- Concentration of oxygen remaining in exhaust gas
- True heat release of gas fuel
- Ratio for judging angle of combustion mass rate (3 locations)
- Value for judging misfire

Saving Analysis Data in CSV Format

You can save absolute pressure analysis data in CSV format (.csv files). You can enter test information prior to saving. The following seven types of items can be saved. Raw data cannot be saved.

- **Test Information**
  - Test date
  - Data name
  - Testing personnel
  - Department
  - Test name
  - Engine type
  - Serial No.
  - Place of test
  - Test bench type
  - Comments
- **Manually Input Data Items**
- **Numeric Analysis Data Items**
- **Crank Angle Graph Data**
- **Cycle Graph Data**
- **Analysis Data for Other Signals**
- **Measured Intake Manifold Pressure, Intake Manifold Temperature, Fuel Consumption, Revolutions per Minute, and Concentration of Oxygen Remaining in Exhaust Gas**

Saving the Analysis Results of a Specified Range of Cycles

For the seven items below, the crank angle graph data from a specified range of cycles can be saved in CSV format (as .csv files).

- Cylinder pressure
- Logarithmic cylinder pressure
- Rate of cylinder pressure rise
- Cylinder gas temperature
- Amount of heat release
- Rate of heat release
- Combustion mass rate

Saving Analysis Conditions

You can save conditions required for analysis in text format (as .ecp or .ecm files).
.ecp: When running the Engine Combustion Pressure Analysis only
.ecm: When running the Monitor Function of Engine Combustion Pressure Analysis

- TDC correction value
- Number of cylinders
- Interval of absolute pressure correction
- Coefficients for conversion to physical values (calibration factors)
- Filter setting conditions
- Calculation parameters
- Calculation execution items
- Analysis graph display conditions
- Screen layout

2.2 Setup

Use the setup program on the CD to install the Engine Combustion Pressure Analysis.
Run the file, *CD Drive* /Disk1/Setup.exe.
If your operating system is Windows NT, 2000, or XP, log in as the administrator.
If a previous version of the software is already installed, you must remove it before installing this version.

2.3 Directory Structure

This software utilizes the following directory structure.

<*Installation directory*> (directory name specified during installation)†

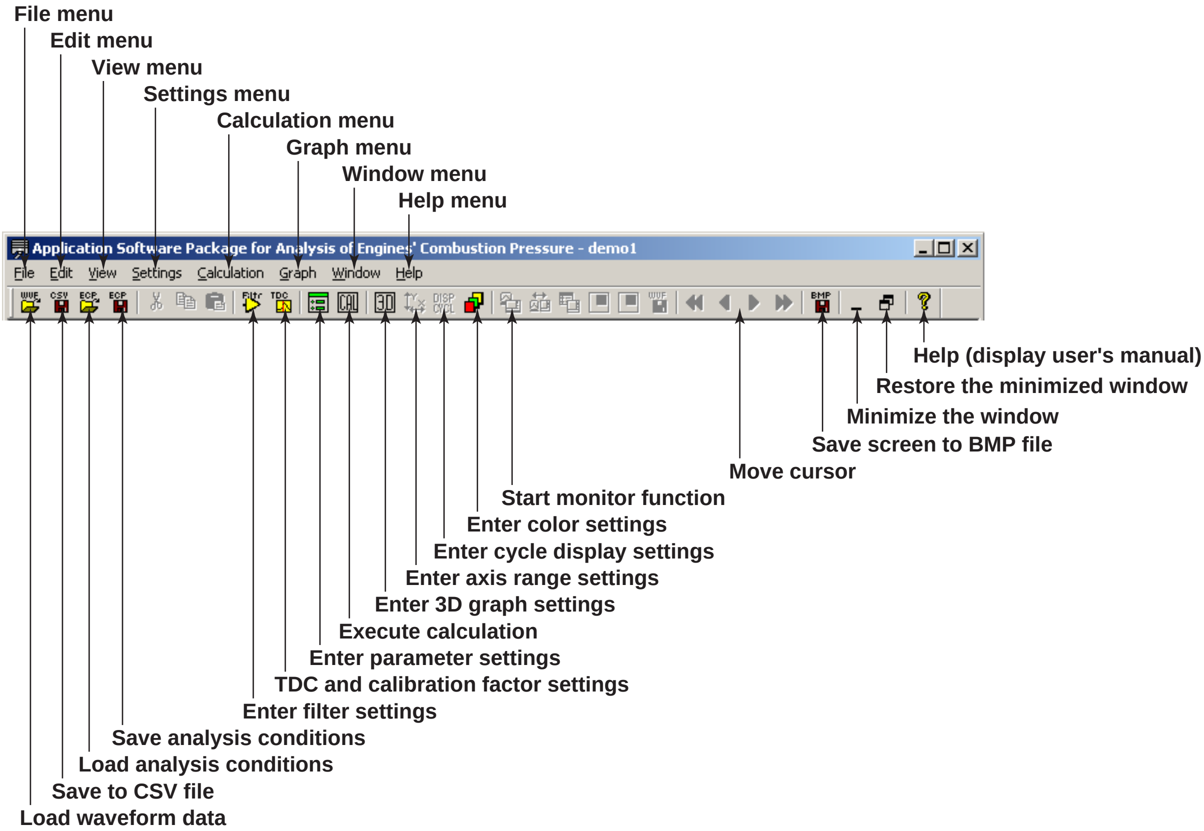
- **<Info>: .ini file directory**
- **<log>: Log file directory (error log, message log)**
- **<work> (for use by application)**
  - **<Cal> (for use by application)**
- **<IM>: User's manual directory (this manual, in PDF format)**
- **<Sample>: Motoring/firing sample data directory**

* If a previous version of the software is already installed, you must remove it before installing this version.

† Only alphabetical characters and numbers may be used for the name of the installation directory.

2.4 Screens

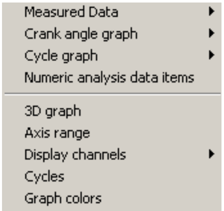
Menu Bar and Icons for the Engine Combustion Pressure Analysis



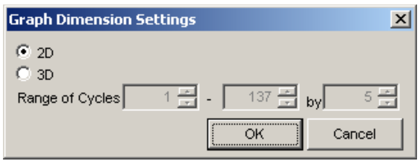
3.1 Common Operations

Right-Clicking the Mouse

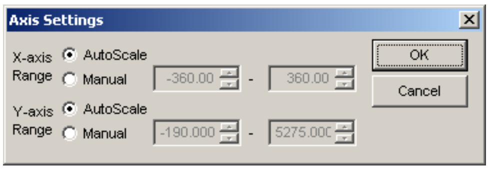
If you right-click on a window displaying a graph, the following shortcut menu appears.



- **Measured Data**: Opens a window displaying a crank angle graph of raw data and corrected data.
- **Crank angle graph**: Opens a window displaying a crank angle graph of calculated analysis items.
- **Cycle graph**: Opens a window displaying a cycle graph of calculated analysis items.
- **Numeric Analysis Data Items**: Opens a window displaying numeric analysis results from calculated analysis items.
- **3D graph**: Displays the graph dimension setting screen. Select 2 or 3 dimensions, and select 3-dimensional graph setting conditions (when the crank angle graph or 3-dimensional analysis graph is displayed).
  The range of cycles extracted from the raw data is set as the maximum range, crank angle data is extracted every number of cycles specified by “by,” and the data is displayed in a 3D graph.

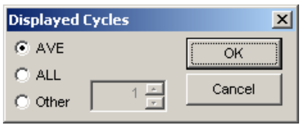


- **Axis range**: Displays the graph axes setting screen. You can set a fixed value for the X and Y axes, or choose Autoscale. These settings are entered for each graph.



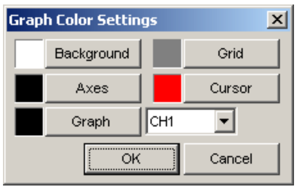
- **Display channels**: Displays a pull-down menu for display channels. This setting is entered for each graph.

- **Cycles**: Displays a setting screen for the displayed cycles. These settings are entered for each graph.



AVE: Displays a cycle average crank angle graph
ALL: Displays superimposed crank angle graphs of all cycles
Other: Displays a crank angle graph of the specified cycles

- **Graph colors**: Displays the graph color setting screen. These settings are entered for each graph.



Moving the Cursor

Values can be read in directly using cursors. If you click in a window displaying a graph, the cursor (a vertical bar) jumps to the point where the mouse was clicked, and the X and Y axes of that point are displayed. Also, the following buttons can be used to move the cursor to the right or left in units of the angular resolution.

 : Fast left cursor

 : Left cursor

 : Right cursor

 : Fast right cursor

Displaying the Mouse Pointer Position

When the mouse is moved over a graph, the X and Y value of the current position is displayed on the graph.

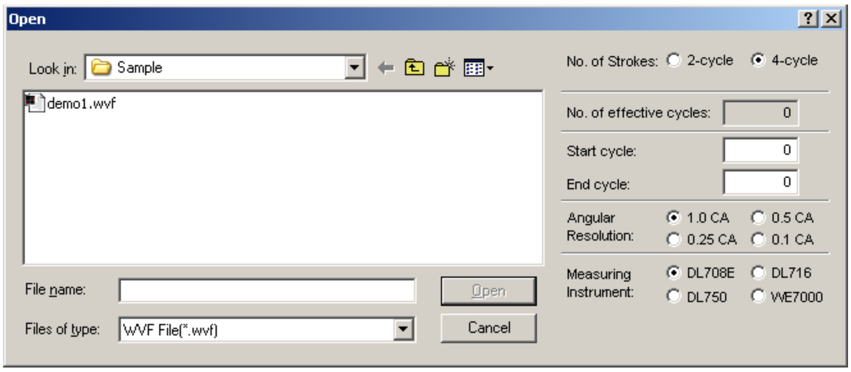
Saving Results to a BMP File

Press the  button to save a bit map image of the active graph window.

Displaying Help Information

You can display the user's manual in PDF format. You can also choose **About ECP** to display version information about the program.

3.2 File > Load Measured Data



Functions

- You can select a measured data file to be loaded.
  Filters can be applied according to the filter settings.
- Set the following for the data to be loaded:
  - Number of strokes
  - Range of cycles to be analyzed
  - Crank angle resolution
  - Model of measuring instrument
- If the measuring instrument is incorrect, a warning message is displayed.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	No. of Strokes	Prev. value	-	-	-	-	S
2	No. of effective cycles	Prev. value	I	5.0	1	25000	N.A.
3	Start cycle	1	I	5.0	1	25000	I
4	End cycle	Number of effective cycles	I	5.0	1	25000	I
5	Angular Resolution	1.0 CA	-	-	-	-	S
6	Measuring Instrument	DL716	-	-	-	-	S

(1) **No. of effective cycles**: When selecting the file to be loaded, the angular resolution is assumed to be 1 CA, and the number of effective cycles is calculated using the equation below. If the angular resolution is changed to 0.5, 0.25, or 0.1, the number of effective cycles is updated accordingly.

(portion before the decimal (no. of measured data / no. of data per cycle)) – 3

The maximum number of effective cycles varies depending on the angular resolution as follows.

- For 1 CA: 25000 cycles
- For 0.5 CA: 12500 cycles
- For 0.25 CA: 6250 cycles
- For 0.1 CA: 2500 cycles

(2) **Start cycle**, **End cycle**: Enter the range of cycles to be analyzed (up to 800 cycles). You cannot enter a value greater than the number of effective cycles for the data under analysis.

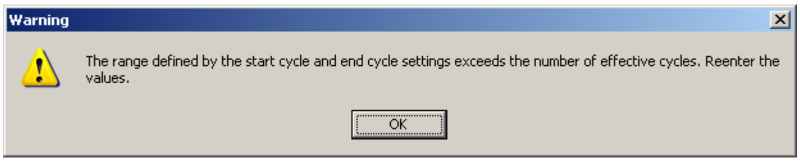
(3) **Angular Resolution**: Select 1, 0.5, 0.25, or 0.1 according to the conditions during measurement.

(4) **Measuring Instrument**: When loading files, the appropriate instrument is automatically selected. You can also change the instrument to the DL708E, DL716, DL750, or WE7000.

Button Operations

Open Button

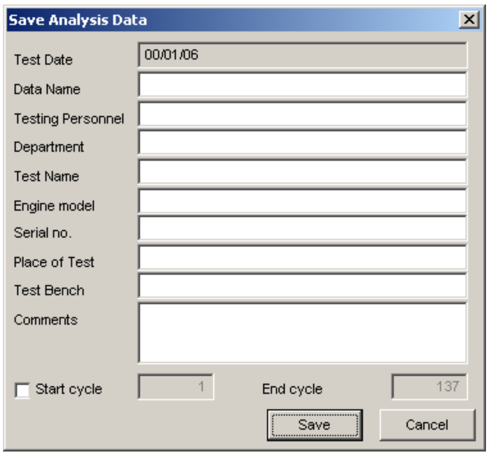
Selects the start and end cycles and advances to the raw data display screen.
If the number of start/end cycles selected exceeds the maximum number of cycles of the data to be analyzed, a message is displayed.



Cancel Button

Clears all screen settings and closes the screen.

3.3 File > Save Analysis Data



Functions

- Test information can be entered and combustion pressure analysis results can be saved to a file in CSV format.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	Data Name	Prev. value	C	8	-	-	I
2	Testing Personnel	Prev. value	C	8	-	-	I
3	Department	Prev. value	C	16	-	-	I
4	Test Name	Prev. value	C	32	-	-	I
5	Engine model	Prev. value	C	16	-	-	I
6	Serial No.	Prev. value	C	16	-	-	I
7	Place of Test	Prev. value	C	16	-	-	I
8	Test Bench	Prev. value	C	16	-	-	I
9	Comments	Prev. value	C	32	-	-	I
10	Start cycle, End cycle	Prev. value	I	5.0	1	25000	I or S

(1) **Start cycle, End cycle**: To save a specified range of cycles of crank angle graph data from the analysis results to a CSV file, choose this command, then enter the range of cycles to be saved. The suffix “-all” is added to the specified file name. For example, if you name the file Sample, the actual file name will change to Sample-all.csv when saved.

Button Operations

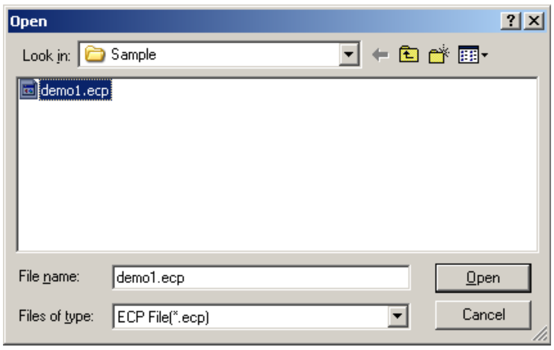
Cancel Button

Clears all screen settings and closes the window.

Save Button

Displays a window allowing you to specify the save location. Clicking OK in that window saves combustion pressure analysis results data to a text file in CSV format. Raw data cannot be saved.

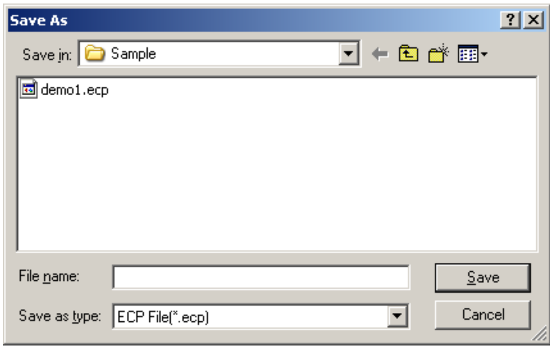
3.4 File > Load Analysis Conditions



Functions

- Loads analysis conditions (TDC correction value, Number of cylinders, interval of absolute pressure correction, coefficients for conversion to physical values (calibration factors), filter setting conditions, calculation parameters, calculation execution items, analysis graph display conditions, screen layout), and places them into effect as the current conditions. However, when choosing this command, all previously calculated results are cleared, and any currently displayed analysis results windows are closed. Display analysis results windows again after calculations have been performed.

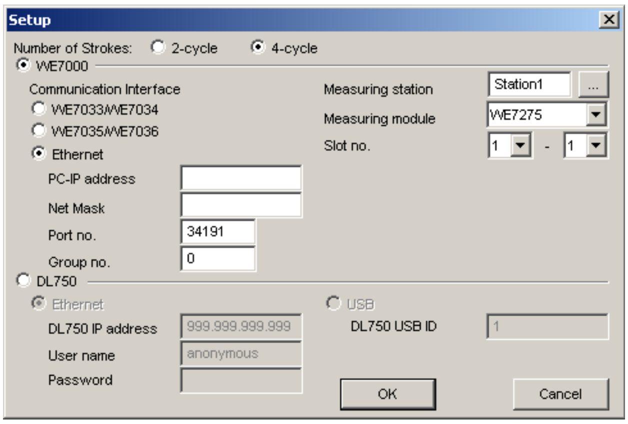
3.5 File > Save Analysis Conditions



Functions

- Saves analysis conditions (TDC correction value, Number of cylinders, interval of absolute pressure correction, coefficients for conversion to physical values (calibration factors), filter setting conditions, calculation parameters, calculation execution items, analysis graph display conditions, screen layout).

3.6 File > Start Monitor Functions



Functions

- Sets the communication interface for the PC, and WE7000 as well as the selected measurement module and slot number.
- Sets the conditions for connection with the DL750.
- Displays the raw data display window.
- You can perform real time monitoring while running the engine combustion analysis package.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	Number of Strokes	Prev. value	-	-	-	-	S
2	WE7000/DL750	Prev. value	-	-	-	-	S
3	Communication Interface	Prev. value	-	-	-	-	S
4	PC-IP address	Prev. value	C	16	-	-	I
5	Net Mask	Prev. value	C	16	-	-	I
6	Port no.	Prev. value	C	5	1	64000	I
7	Measuring station	Prev. value	C	16	-	-	I
8	Measuring module	Prev. value	-	-	-	-	S
9	Slot no.	Prev. value	-	-	-	-	S
10	Ethernet/USB	Prev. value	-	-	-	-	S
11	DL750 IP address	Prev. value	C	16	-	-	I
12	User name	Prev. value	C	16	-	-	I
13	Password	Prev. value	C	16	-	-	I
14	DL750 USB ID	Prev. value	C	3	-	-	I

(1) **Number of Strokes**: Select a 2- or 4-cycle engine
(2) **WE7000/DL750**: Select the WE7000 or DL750 for the measuring instrument.
(3) **Communication Interface** (WE7000): Select Optical/Ethernet.

(4) **PC-IP address**/**Net Mask**/**Port no.**: If Ethernet is selected for the communication interface, enter the IP address, net mask, and port number of the PC. If the PC has only one network interface, the IP address and net mask will be automatically assigned if you leave these fields blank.

(5) **Measuring station**: Enter the WE7000 station name.

(6) **Measuring module**: Select the WE7235, WE7245, WE7271/WE7272, or WE7275.

(7) **Slot no.**: Select the number of installed slots. A range is indicated when multiple modules are used. When one module is used, enter the same number into both boxes.

(8) **Ethernet/USB** (DL750): Select Ethernet/USB.

(9) **DL750 IP address**: Enter the IP address for the DL750.

(10) **User name**: Enter the user name for connecting with the DL750.

(11) **Password**: Enter the password for connecting with the DL750. When the user name is anonymous, no password is required.

(12) **DL750 USB ID**: Enter the USB ID of the instrument in the range from 1 to 127.

Button Operations

OK Button

Activates the settings entered in the screen, opens a connection with the measuring instrument, and closes the window.

Cancel Button

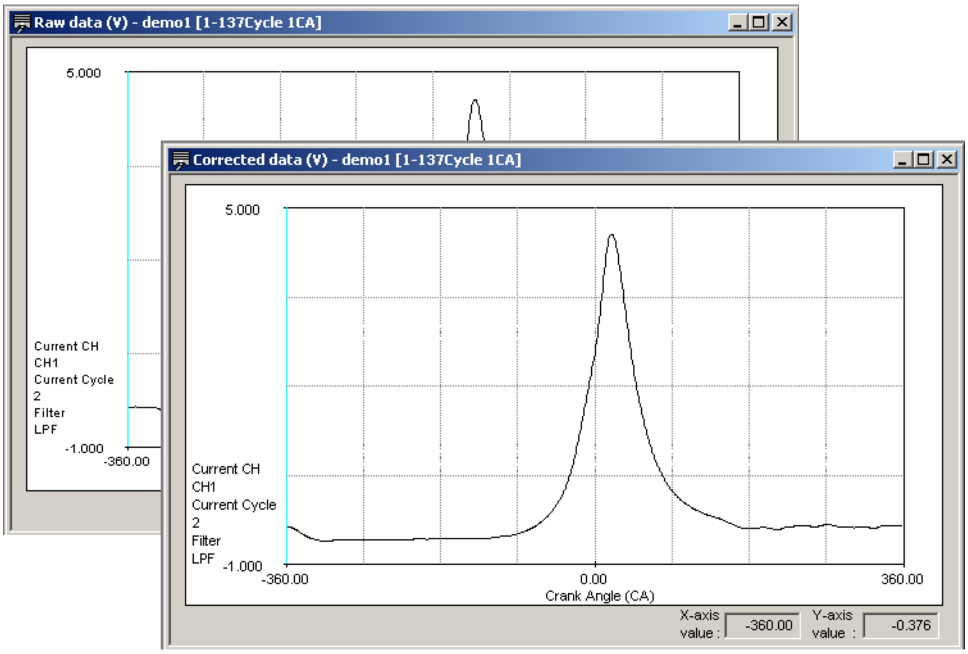
Clears all on-screen settings, and closes the window.

3.7 File > Close

Functions

- All windows accessing the data files used for the current window are closed.
- The current analysis results are not saved.

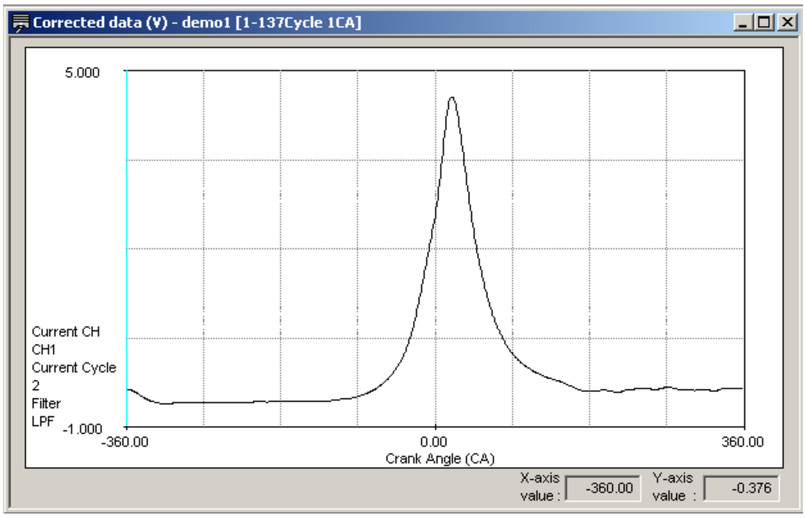
3.8 View > Measured Data



Functions

- Filters are applied to raw data according to the filter settings, and a crank angle graph is displayed.
- The following are displayed depending on the command used.
  View > Measured data > Raw data: Raw data before TDC correction
  View > Measured data > Corrected data: Raw data after TDC correction
- The data name, cycle range, and angular resolution is displayed in the title bar of the window.
- Shows the displayed channels, displayed cycles, and the current filter settings.
- When filter settings are entered, the display is updated.

3.9 View > Crank Angle Graph



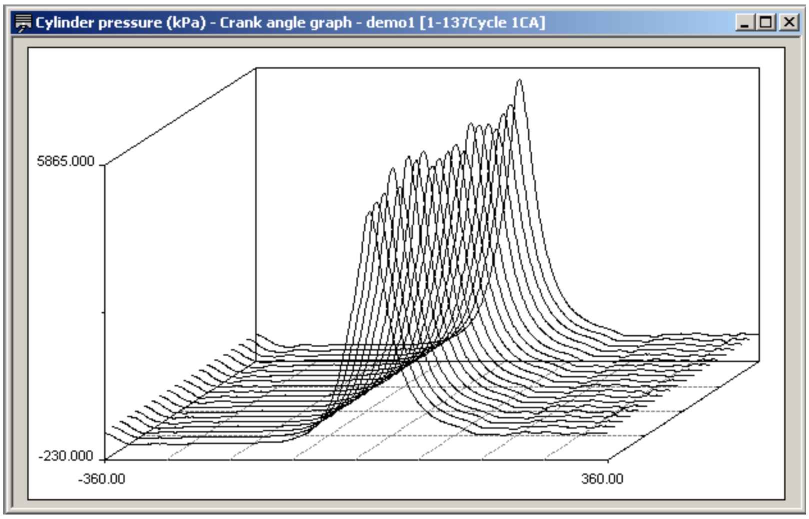
Functions

- Displays a crank angle graph of the combustion pressure analysis results.
- The selected values from the cycle graph data items and the measurement items set to *Use in Calculations* in the Parameter Settings screen are displayed in the lower right portion of the screen.

  The following shows how the displayed contents varies depending on the settings for displayed channels and displayed cycles (see section 3.1, "Common Operations").

Display Channels	Cycles	Displayed Value
Specified channel	Specified cycle	Value for specified cycles
	AVE	Same values as in the numeric analysis data item screen
	ALL	None
ALL	-	None

If you select “3D” on the Graph Dimension Settings screen (see section 3.1, “Common Operations”), the following 3D display appears.



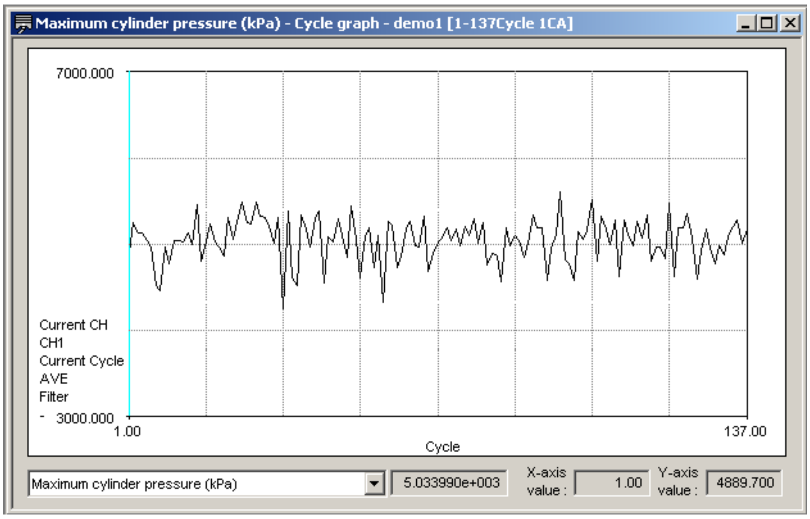
Functions

- Crank angle display data is extracted each number of specified cycles from the specified range of cycles, and a 3D graph is displayed.
- The maximum number of cycles that can be displayed is 20.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	Range of Cycles	Extracted cycles	I	3	1	800	I

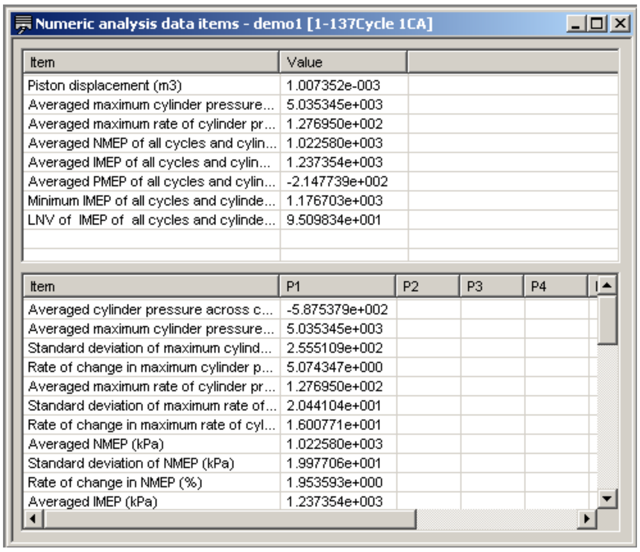
3.10 View > Cycle Graph



Functions

- Displays a cycle graph of the combustion pressure analysis results.
- The average values (the same values displayed in the numeric analysis data items screen) of the selected cycle graph data items and the measurement items set to *Use in Calculations* in the Parameter Settings screen are displayed in the lower part of the screen.

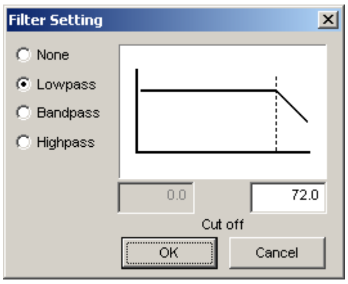
3.11 View > Numeric Analysis Data Items



Functions

- Displays the numeric analysis data items of the combustion pressure analysis results.

3.12 Settings > Filter



Functions

- You can perform digital filter processing on raw data. If the raw or corrected data has already been displayed, filters are automatically applied and the display is updated. However, this does not affect current analysis results. All calculated results are cleared, and any currently displayed analysis results windows are closed. Display analysis results windows again after calculations have been performed.
- You can select None, Lowpass, Bandpass, or Highpass filters.
- The filter function is a 4th order Butterworth (24 db/oct).
- The cutoff frequency is set in numbers of orders (multiples) since data acquisition uses synchronization with the rotation pulse.
- When filters are applied, any TDC correction and combustion pressure analysis performed thereafter is done on filtered data.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	*Filter type*	Prev. value	-	-	-	-	S
2	Cutoff	Prev. value	F	6.1	7.2	720	I

(1) ***Filter type***: Select None, Lowpass, Bandpass, or Highpass for the filter.

(2) **Cutoff**: The cutoff can be set in the following ranges:
At 1 CA resolution, 7.2 order (times) to 72 order (times) of the number of revolutions
At 0.5 CA resolution, 14.4 order (times) to 144 order (times) of the number of revolutions
At 0.25 CA resolution, 28.8 order (times) to 288 order (times) of the number of revolutions
At 0.1 CA resolution, 72 order (times) to 720 order (times) of the number of revolutions

Button Operations

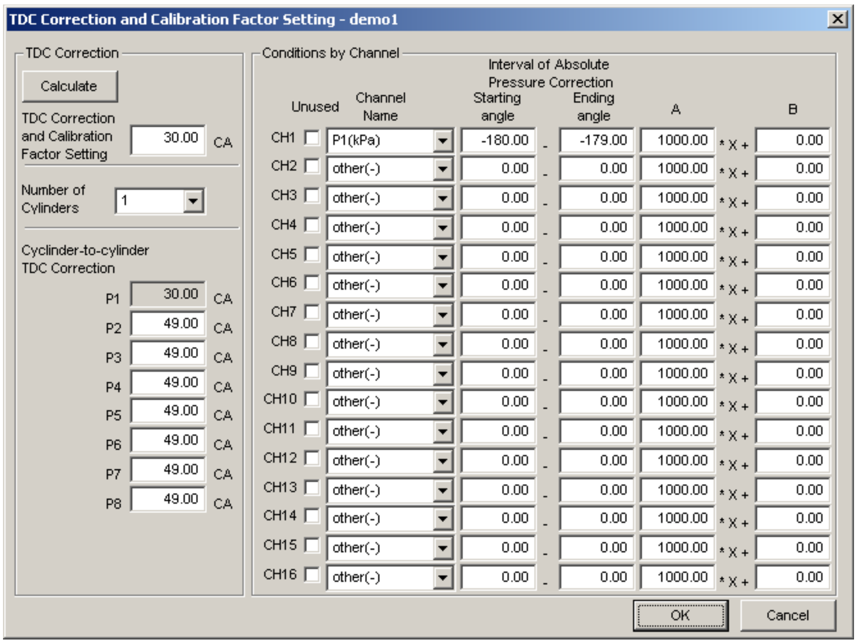
OK Button

Activates filters conditions, applies filters to raw data, and closes the window.

Cancel Button

Clears all on-screen settings, and closes the window.

3.13 Settings > TDC Correction and Calibration Factor Settings



Functions

- The TDC correction value can be calculated using one cycle's worth of all-cycle-averaged motoring data from cylinder 1 (P1).
  The calculated TDC correction value is added to the difference in angle between cylinders according to the specified number of cylinders (for example at 4 cycles and 4 cylinders) in the following manner: 0 + calculated TDC correction value, 180 + calculated TDC correction value, 360 + calculated TDC correction value, 540 + calculated TDC correction value, then the cylinder-to-cylinder TDC correction value is automatically set.
  You can also set the cylinder-to-cylinder TDC correction values manually (excluding P1).
- Signal assignments can be entered.
  You can assign channels to cylinder pressure (up to eight cylinder's worth), intake manifold pressure, intake manifold temperature, fuel consumption, revolutions per minute, and other signals.
- The cylinder pressure signals undergo TDC correction per the specified TDC correction value.
- Cylinder pressure measurements take place in the cylinder's firing order, with the assumption that all signals are assigned to contiguous channels starting with channel 1.
- You can specify channels to be excluded from combustion pressure analysis.
- If the raw or corrected data has already been displayed, settings are automatically applied and the display is updated. However, this does not affect current analysis results. When changing these settings, all previously calculated results are cleared, and any currently displayed analysis results windows are closed. Display analysis results windows again after calculations have been performed.

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	*Calculated TDC Correction Value*	Calculated value	F	7.2	(*1)	(*2)	I
2	Number of Cylinders	Prev. value	I	2.0	1	8	S
3	Cylinder-to-cylinder TDC Correction	Calculated value	F	7.2	(*1)	(*3)	I
4	Unused	None	-	-	-	-	S
5	Channel Name	None	-	-	-	-	S
6	Interval of Absolute Pressure Correction	Prev. value	F	7.2	(*1)	(*2)	I
7	A	Prev. value	F	8.2	1	99999.99	I
8	B	Prev. value	F	8.2	1	99999.99	I

*1: 4 cycles = –360; 2 cycles = –180
*2: 4 cycles = –359.9; 2 cycles = –179.9
*3: 4 cycles = –1079.9; 2 cycles = –539.9

(1) ***Calculated TDC Correction Value***: Displays the TDC correction values calculated using the average of all cycles of the first cylinder (P1). The value can also be entered manually. When the OK button is used, this value is rounded to the angular resolution and applied to each channel.

(2) **Number of Cylinders**: Specified for automatic calculation of the cylinder-to-cylinder correction value. If the value is changed, click the Calculate button to recalculate the results.

(3) **Cylinder-to-cylinder TDC Correction**: The calculated TDC correction value is added to the difference in the crank angle. For example, with a 4-cycle engine: 4 cylinders = 180 CA, 6 cylinders = 120 CA, and 8 cylinders = 90 CA. You can also set the value manually (excluding P1).

(4) **Unused**: Selected channels are ignored during analysis. CSV files are also not saved.

(5) **Channel Names**: Signals are assigned to channels 1 through 16. Select the signal type from the options below.

P1 to P8: Cylinder pressure in the order of firing
Pitk: Intake manifold pressure
FC: Fuel consumption
Ne: Revolutions per minute
Td: Intake manifold temperature
EXTo2: Concentration of oxygen remaining in exhaust gas
Other: Other Signals

For signals other than P1 through P8, TDC correction is performed based on the 1st cylinder.

This measured data can be used when measuring intake manifold pressure, fuel consumption, revolutions per minute, and intake manifold temperature, and performing analysis. The average value at each cycle can be saved to a .csv file. Other signals can be displayed in a crank angle graph or cycle graph, and that graphical data can be saved in CSV format.

(6) **A**, **B**: The measured voltage signals are converted to physical values using the equation y = Ax + B.

Button Operations

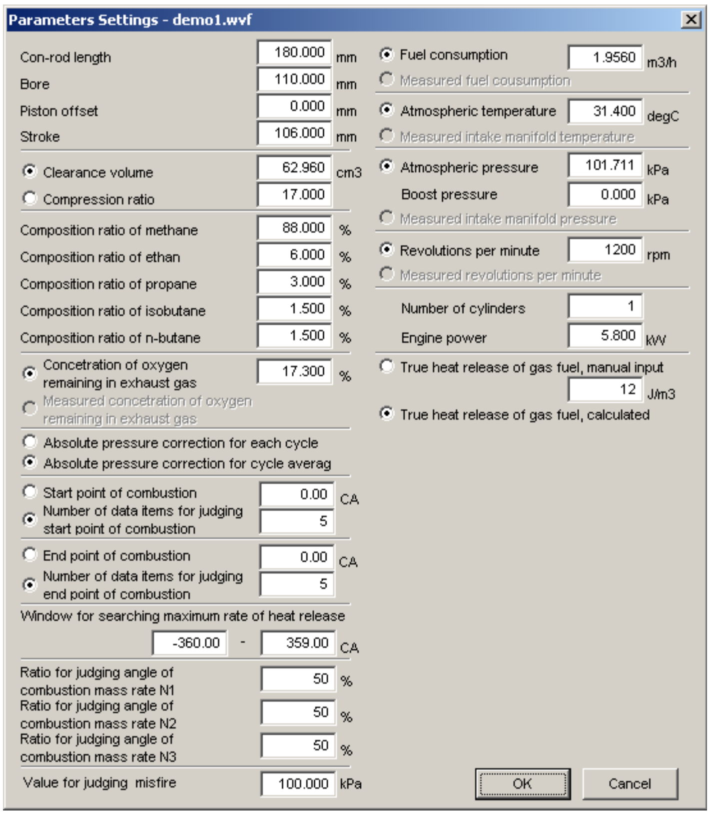
OK Button

Activates all on-screen settings, and closes the window.

Cancel Button

Clears all on-screen settings, and closes the window.

3.14 Calculation > Set Parameters



Functions

- Lets you enter necessary engine and other parameters for combustion pressure analysis.
- You can select either Clearance volume or Compression ratio.
- Enter the number of data from which to determine the start and end of combustion. Or, enter the combustion start and end values directly.
- Specify the range for searching for the maximum rate of heat release.
- Select the method of absolute pressure correction.
- Select whether or not to use this measured data for analysis when measuring intake manifold pressure, fuel consumption, revolutions per minute, intake manifold temperature, and concentration of oxygen remaining in exhaust gas.
- When changing these settings, all previously calculated results are cleared, and any currently displayed analysis results windows are closed. Display analysis results windows again after calculations have been performed.

Setting/Display Data

No.	Item	Unit	Default Setting	Data Type	Size	Numerical Data Min. Value	Numerical Data Max. Value	Input (I) or Select (S)
1	Con-rod Length	mm	Prev. value	F	9.3	0.000	99999.999	I
2	Bore	mm	Prev. value	F	9.3	0.000	99999.999	I
3	Piston offset	mm	Prev. value	F	9.3	0.000	99999.999	I
4	Stroke	mm	Prev. value	F	9.3	0.000	99999.999	I
5	Clearance volume	cm^3	Prev. value	F	9.3	0.000	99999.999	I or S
6	Compression ratio	-	Prev. value	F	6.3	0.000	99999.999	I or S
7	Composition ratio of methane	%	Prev. value	F	6.2	0	100.00	I
8	Composition ratio of ethane	%	Prev. value	F	6.2	0	100.00	I
9	Composition ratio of propane	%	Prev. value	F	6.2	0	100.00	I
10	Composition ratio of isobutane	%	Prev. value	F	6.2	0	100.00	I
11	Composition ratio of n-butane	%	Prev. value	F	6.2	0	100.00	I
12	Concentration of oxygen remaining in exhaust gas(%)	%	Prev. value	F	6.2	0	100.00	I
13	Measured concentration of oxygen remaining in exhaust gas	-	-	-	-	-	-	S
14	Fuel consumption	m^3/h	Prev. value	F	9.3	0.000	99999.999	I or S
15	Measured fuel consumption	-	-	-	-	-	-	S
16	Atmospheric temperature	°C	Prev. value	F	9.3	–273.000	99999.999	I or S
17	Measured intake manifold temperature	-	-	-	-	-	-	S
18	Atmospheric pressure	kPa	Prev. value	F	9.3	0.000	99999.999	I or S
19	Measured intake manifold pressure	-	-	-	-	-	-	S
20	Revolutions per minute	rpm	Prev. value	I	5.0	0	99999	I or S
21	Measured revolutions per minute	-	-	-	-	-	-	S
22	Number of cylinders	-	Prev. value	I	1.0	1	8	I
23	Engine power	kW	Prev. value	F	9.3	0	99999.999	I
24	Boost pressure	kPa	Prev. value	F	7.3	0.000	999.999	I
25	True heat release of gas fuel	J	Prev. value	F	9.3	0.000	999999999.9	I or S
26	Start point of combustion	CA	Prev. value	F	6.2	–360.00	359.99	I
27	Number of data items for judging start point of combustion	-	Prev. value	I	2.0	3	99	I
28	End point of combustion	CA	Prev. value	F	6.2	–360.00	359.99	I
29	Number of data items for judging end point of combustion	-	Prev. value	I	2.0	3	99	I
30	*Method of absolute pressure correction*	-	-	-	-	-	-	S
31	Window of searching maximum rate of heat release	CA	Prev. value	F	6.2	–360.00	359.99	I
32	Ratio for judging angle of combustion mass rate	%	Prev. value	I	2.0	5	95	I
33	Value for judging misfire	kPa	Prev. value	F	9.3	0.000	99999.999	I

(1) **Start point of combustion**: The specified value (without searching).

(2) **End point of combustion**: The specified value (without searching).

(3) **Window of searching maximum rate of heat release**: Set the range for finding the maximum angle of the rate of heat release used as the standard for searching for the start and end points of combustion.

(4) **Ratio for judging angle of combustion mass rate**: Determines the crank angle at which the combustion mass rate matches the specified percentage.

(5) **Value for judging misfire**: Cycles for which the IMEP is lower than this setting are judged as misfires, and the rate of misfire is determined by the ratio of the number of misfiring cycles relative to the total number of cycles.

(6) **Measured concentration of oxygen remaining in exhaust gas**: Select this item when measuring the concentration of oxygen remaining in exhaust gas and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that concentration of oxygen remaining in exhaust gas (EXTo2) is assigned to a channel.

(7) **Measured fuel consumption**: Select this item when measuring the fuel consumption and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that fuel consumption (Fc) is assigned to a channel.

(8) **Measured intake manifold temperature**: Select this item when measuring the temperature of the intake manifold and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that fuel consumption(Td) is assigned to a channel.

(9) **Measured intake manifold pressure**: Select this item when measuring the pressure in the intake manifold and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that intake manifold pressure (Pitk) is assigned to a channel.

(10) **Measured revolutions per minute**: Select this item when measuring rpm's and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that rpm (Ne) is assigned to a channel.

Button Operations

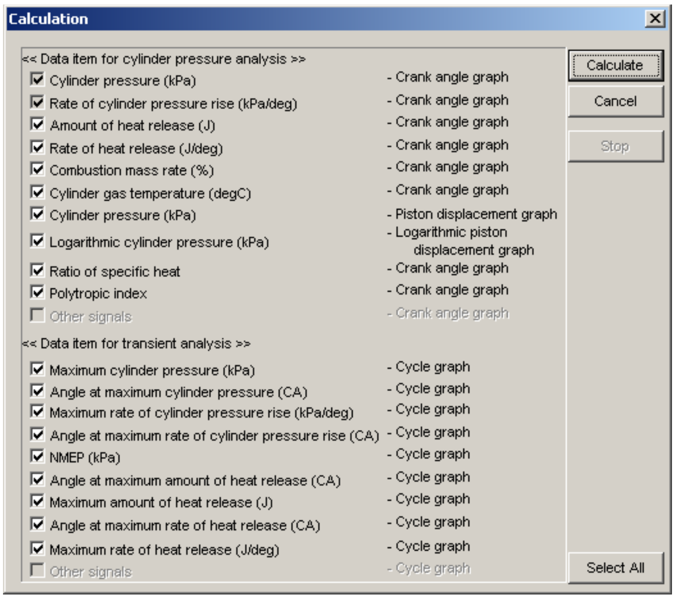
OK Button

Activates all on-screen settings and closes the window. The settings take effect for the next calculation.

Cancel Button

Clears all on-screen settings, and closes the window.

3.15 Calculation > Calculate



Functions

- You can select items to undergo combustion pressure analysis, then execute the analysis. Cylinder pressure and rate of cylinder pressure rise are always analyzed.
- The progress of the combustion pressure calculation is shown by the filling in of each check box. If a particular calculation is impossible, the item is skipped and the software advances to the next item.

Button Operations

Calculate Button:

Calculates the selected analysis items (including related calculations).

Close Button:

This button appears when calculation ends. Closes the window.

Cancel Button

This button disappears when calculation is started.

Closes the window.

Stop Button

Stops calculation.

Select All Button

Selects all items for analysis.

3.16 Graph

Functions

- These are the same functions as the ones described in section 3.1, “Common Operations.”
  They include graph dimension settings, axis settings, displayed channels, displayed cycles, and graph color settings.

3.17 Window > Cascade

Functions

- Arranges all open windows in a cascading fashion.

3.18 Window > Tile

Functions

- Arranges all open windows in a non-overlapping fashion.

3.19 Window > Arrange Icons

Functions

- Arranges minimized icons.

3.20 Window > Minimize

Functions

- Minimizes all windows accessing the same data.
- Minimizes all monitor function windows.

3.21 Window > Restore

Functions

- Restores all minimized windows that were accessing the same data.
- Restores all minimized monitor function windows.

4.1 Saved Items

Test Information, Manually Input Data Items

- **Test Information**
  Test date
  Data name
  Testing personnel
  Department
  Test name
  Engine type
  Serial No.
  Place of test
  Test bench type
  Comments

- **Manually Input Data Items**
  Calculated TDC correction value (CA)
  Number of cylinders
  Channel-by-channel TDC correction value (CA)
  Channel-by-channel calibration factor A (kPa/V)
  Channel-by-channel calibration factor B (kPa/V)
  Channel-by-channel used/unused (1: Used)
  Starting angle of correction interval (CA)
  Ending angle of correction interval (CA)
  Channel name
  Con-rod length (m)
  Bore (m)
  Piston offset (m)
  Stroke length (m)
  Clearance volume (m^3)
  Compression ratio
  Composition ratio of methane (%)
  Composition ratio of ethane (%)
  Composition ratio of propane (%)
  Composition ratio of isobutane (%)
  Composition ratio of n-butane (%)
  Concentration of oxygen remaining in exhaust gas (%)
  Fuel Consumption (m^3/h)
  Atmospheric Temperature (°C)
  Atmospheric pressure (kPa)
  Revolutions per minute (rpm)
  Number of cylinders
  Engine power (kW)
  Boost pressure (kPa)
  True heat release of gas fuel (J/m^3)
  Method of absolute pressure correction
  Angle for start point of combustion (point a) (CA)
  Number of data items for judging start point of combustion
  Angle for end point of combustion (point b) (CA)
  Number of data items for judging end point of combustion
  Start point of searching maximum rate of heat release (CA)

End point of searching maximum rate of heat release (CA)
Ratio for judging angle of combustion mass rate N1 (%)
Ratio for judging angle of combustion mass rate N2 (%)
Ratio for judging angle of combustion mass rate N3 (%)
Value for judging misfire (kPa)

Calculation Results

- **Calculation Data Items: Numeric Analysis Data**

Average cylinder pressure across correction interval (kPa)
Averaged maximum cylinder pressure (kPa)
Standard deviation of maximum cylinder pressure (kPa)
Rate of change in maximum cylinder pressure (%)
Averaged maximum rate of cylinder pressure rise (kPa/deg)
Standard deviation of maximum rate of cylinder pressure rise (kPa/deg)
Rate of change in maximum rate of cylinder pressure rise (%)
Piston displacement (m^3)
Averaged NMEP (kPa)
Standard deviation of NMEP (kPa)
Rate of change in NMEP (%)
Averaged IMEP (kPa)
Standard deviation of IMEP (kPa)
Rate of change in IMEP (%)
Averaged PMEP (kPa)
Standard deviation of PMEP (kPa)
Rate of change in PMEP (%)
Averaged maximum cylinder gas temperature (°C)
Standard deviation of maximum cylinder gas temperature (°C)
Rate of change in maximum cylinder gas temperature (%)
Averaged maximum rate of heat release (J/deg)
Standard deviation of maximum rate of heat release (J/deg)
Rate of change in maximum rate of heat release (%)
Averaged maximum amount of heat release (J)
Standard deviation of maximum amount of heat release (J)
Rate of change in maximum amount of heat release (%)
Averaged angle at combustion mass rate N1 % (CA)
Standard deviation of angle at combustion mass rate N1 % (CA)
Rate of change in angle at combustion mass rate N1 % (%)
Averaged angle at combustion mass rate N2 % (CA)
Standard deviation of angle at combustion mass rate N2 % (CA)
Rate of change in angle at combustion mass rate N2 % (%)
Averaged angle at combustion mass rate N3 % (CA)
Standard deviation of angle at combustion mass rate N3 % (CA)
Rate of change in angle at combustion mass rate N3 % (%)
Average start point of combustion (point a) (CA)
Average end point of combustion (point b) (CA)
Minimum value of IMEP (kPa)
LNV of IMEP (%)
Rate of misfire (%)
Averaged maximum cylinder pressure of all cycles and cylinders (kPa)
Averaged maximum rate of cylinder pressure rise of all cycles and cylinders (kPa/deg)
Averaged NMEP of all cycles and cylinders (kPa)

Averaged IMEP of all cycles and cylinders (kPa)
Averaged PMEP of all cycles and cylinders (kPa)
Minimum IMEP of all cycles and cylinders (kPa)
LNV of IMEP of all cycles and cylinders (%)
Oxygen requirement (m^3)
Exhaust gas volume (m^3)
Theoretical air (m^3)
Theoretical exhaust gas volume (m^3)
Amount of water produced (m^3)
Theoretical volume of dry exhaust gas (m^3)
Excess air factor (m^3)
Intake air volume (m^3/h)
Intake fuel-air mixture volume (m^3/h)
Volumetric efficiency (%)
Specific gravity of fuel gas
Mass of intake air (kg)
Mass of intake fuel (kg)
Mass of intake gas mixture (kg)
Gas mixture constant (J/kg.K)
True heat release of gas fuel (J/m^3)
Cooling loss (J)
Cooling loss ratio (%)
Brake thermal efficiency (%)
Friction loss (%)
Combustion efficiency (%)
Degree of constant volume
Indicated efficiency (%)

- **Calculation Data Items: Crank Angle Graph Data Items**

Crank angle
Average cylinder pressure (kPa)
Logarithmic average cylinder pressure (kPa)
Piston displacement (m)
Rate of cylinder volume increase (m^3/deg)
Piston displacement (m^3)
Logarithmic cylinder volume (m^3)
Average rate of cylinder pressure rise (kPa/deg)
Average cylinder gas temperature (°C)
Average rate of heat release (J/deg)
Average amount of heat release (J)
Average combustion mass rate (%)
Raito of specific heat
Polytropic index

- **Calculation Data Items: Cycle Graph Data Items**
  Cycle
  Maximum cylinder pressure (kPa)
  Crank angle at maximum cylinder pressure (CA)
  Averaged maximum cylinder pressure of all cylinders (kPa)
  Averaged crank angle at maximum cylinder pressure of all cylinders (CA)
  Maximum rate of cylinder pressure rise (kPa/deg)
  Crank angle at maximum rate of cylinder pressure rise (CA)
  Averaged maximum rate of cylinder pressure rise of all cylinders (kPa/deg)
  Averaged angle at maximum rate of cylinder pressure rise of all cylinders (CA)
  Compression/expansion work (J)
  Pumping loss (J)
  NMEP (kPa)
  Averaged NMEP of all cylinders (kPa)
  IMEP (kPa)
  Averaged IMEP of all cylinders (kPa)
  PMEP (kPa)
  Averaged PMEP of all cylinders (kPa)
  Maximum cylinder gas temperature (°C)
  Crank angle at maximum cylinder gas temperature (CA)
  Maximum rate of heat release (J/deg)
  Crank angle at maximum rate of heat release (CA)
  Maximum amount of heat release (J)
  Crank angle at maximum amount of heat release (CA)
  Angle at combustion mass rate N1 % (CA)
  Angle at combustion mass rate N2 % (CA)
  Angle at combustion mass rate N3 % (CA)
  Start point of combustion (point a) (CA)
  End point of combustion (point b) (CA)

  * When carrying out a per-cycle absolute pressure correction, the per-cycle absolute pressure correction value are left in the Calculation Item: Cycle Graph Data field.

- **Calculation Data Items: Crank Angle Graph Data (Other Signals)**
  Crank angle
  Intake manifold pressure (kPa)
  Fuel consumption (m^3/h)
  Revolutions per minute (rpm)
  Intake manifold temperature (°C)
  Concentration of oxygen remaining in exhaust gas (%)
  Other signals (Crank angle graph data)

- **Calculation Data Items: Cycle Graph Data Items (Other Signals)**
  Cycle
  Intake manifold pressure (kPa)
  Fuel consumption (m^3/h)
  Revolutions per minute (rpm)
  Intake manifold temperature (°C)
  Concentration of oxygen remaining in exhaust gas (%)
  Other signals (Cycle graph data)

Crank Angle Graph Data of Specified Range of Cycles

Crank angle
Cylinder pressure (kPa)
Rate of cylinder pressure rise (kPa/deg)
Cylinder gas temperature (°C)
Rate of heat release (J/deg)
Amount of heat release (J)
Combustion mass rate (%)
Ratio of specific heat
Intake manifold pressure (kPa)
Fuel consumption (m^3/h)
Revolutions per minute (rpm)
Intake manifold temperature (°C)
Concentration of oxygen remaining in exhaust gas (%)
Other signals (Crank angle graph data)

* Intake manifold pressure, fuel consumption, rpm, intake manifold temperature, and concentration of oxygen remaining in exhaust gas are saved only when they are measured.

5.1 Explanation of Equations

In the explanations below, 720 indicates the angle at cycle 1 for a 4-cycle engine. Substitute 360 for a 2-cycle engine.

1. Pθ in

Cylinder pressure (kPa) of the specified range of cycles extracted after rotational offset correction and TDC correction

Pθ in = A × U[720,N] + B

N:	Number of cycles
U:	Voltage value (measured value) of the specified range of cycles extracted after rotational offset correction and TDC correction (V)
A, B:	Sensor calibration factor (kPa/V) (manually input)

2. Padj[N]

Average cylinder pressure (kPa) of the specified crank angle range used for the absolute pressure correction

For per-cycle average
Padj[N] = ave(Pθ in[θ = adj θ1 to adj θ2,N]) # *ave: average value*
For all-cycle average
Padj[N] = ave(Pθ in_ave[θ = adj θ1 to adj θ2]) # *ave: average value*

N:	Number of cycles
Pθ in:	Cylinder pressure (kPa) (calculated value) of the specified range of cycles extracted after rotational offset correction and TDC correction
Pθ in_ave:	Average cylinder pressure (kPa) (calculated value) Pθ in_ave[720] = (1 / N) × Σ(Pθ in[720,N])
adj θ1:	Starting angle (CA) of the range used for absolute pressure correction (manually input)
adj θ2:	Ending angle (CA) of the range used for absolute pressure correction (manually input)

3. Pitk_ave[N]

Average intake manifold pressure at each cycle (kPa)

When intake manifold pressure is set to be measured and used in calculations:
Pitk_ave[N] = ave(Pθ itk[720,N]) # *ave: average value*

N:	Number of cycles
Pθ itk:	Intake manifold pressure (kPa) (measured value)

4. Pθ [720, N]

Cylinder pressure after absolute pressure correction (kPa)

- When the atmospheric and boost pressures are manually input,
  Pθ [720,N] = Pθ in[720, N] – Padj[N] + Pa + Pt
- When depending on the measured intake manifold pressure,
  Pθ [720,N] = Pθ in[720,N] – Padj[N] + Pitk_ave [N]

N:	Number of cycles
Pθ in:	Cylinder pressure (kPa) after rotational offset correction and TDC correction (calculated value)
Padj:	Average cylinder pressure across correction interval (kPa) (calculated value)
Pa:	Atmospheric pressure (kPa) (manually input)
Pt:	Boost pressure (kPa) (manually input)
Pitk_ave:	Average intake manifold pressure (kPa) (calculated value)

5. logPθ [720, N]

Logarithmic cylinder pressure (kPa)

$logP\theta\ [720,N] = \log_{10}(P\theta\ [720,N])$

N: Number of cycles
Pθ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

6. Pθ ave[720]

Average cylinder pressure (kPa)

$P\theta\ ave[720] = (1 / N) \times \Sigma(P\theta[720,N])$

N: Number of cycles
Pθ: Cylinder pressure (kPa) after absolute pressure correction (calculated value)

7. logPθ ave[720]

Logarithmic average cylinder pressure (kPa)

$logP\theta\ ave[720] = \log_{10}(P\theta\ ave[720])$

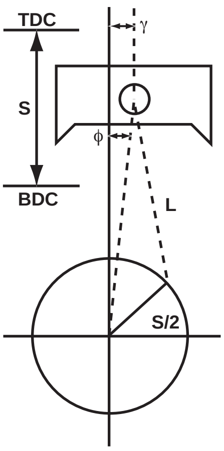
Pθ ave: Average cylinder pressure (kPa) (calculated value)

8. Xθ [720]

Piston displacement (m)

$R = S / 2$
$\phi = \arcsin(\gamma / (L+R))$
$X\theta\ [720] = sqrt\ ((R+L)^2 - \gamma^2) - R \times \cos((\theta + \alpha) \times (pi / 180) + \phi)$
$- sqrt(L^2 - (-R \times \sin((\phi + \alpha) \times (pi / 180) + \phi) + \gamma)^2)$ *# sqrt: quare root*

S: Stroke length (m) (manually input)
L: Con-rod length (m) (manually input)
γ: Piston offset (m) (manually input)
θ: Crank angle (CA) radian
 4-cycle engine: –360 to +359 CA: at 1 CA resolution
 2-cycle engine: –180 to +179 CA: at 1 CA resolution
α: The numbers to the right of the decimal of the TDC correction value (CA) (calculated or manually input). In other words, given an angular resolution of 1 CA, the value is (θ +α) = 0+α, 1+α, . . .
pi: The circular constant



9. Vθ [720]

Piston displacement (m^3)

When **Clearance volume** is selected on the Parameter Settings screen
$V\theta\,[720] = (pi / 4) \times B^2 \times X\theta\,[720] + Vc$
When **Compression ratio** is selected on the Parameter Settings screen
$V\theta\,[720] = (pi / 4) \times B^2 \times X\theta\,[720] + Vst / (Cr-1)$

pi:	The circular constant
B:	Bore (m) (manually input)
Xθ:	Piston displacement (m) (calculated value)
Vc:	Clearance volume (m^3) (manually input)
Vst:	Piston displacement (m^3) (calculated value)
Cr:	Compression ratio (manually input)

10. dVθ [720]

Rate of piston displacement increase (m^3/deg)

$dV\theta\,[720] = (V\theta_{n-2} - 8 \times V\theta_{n-1} + 8 \times V\theta_{n+1} - V\theta_{n+2}) / (12 \times res)$
When the angular resolution is 1 CA, the calculation is made as shown below.
When n = 1 or 2, $(V\theta_{n-2}, V\theta_{n-1}) = (V\theta_{719}, P\theta_{720})$ or $(V\theta_{720}, V\theta_{001})$
When n = 719 or 720, $(V\theta_{n+1}, V\theta_{n+2}) = (V\theta_{720}, V\theta_{001})$ or $(V\theta_{001}, V\theta_{002})$

Vθ:	Piston displacement (m^3) (calculated value)
res:	Angular resolution (1, 0.5, 0.25, or 0.1 CA)

11. logVθ [720]

Logarithmic piston displacement (m^3)

$logV\theta\,[720] = \log_{10}(V\theta\,[720])$

Vθ :	Piston displacement (m^3) (calculated value)

12. dPθ [720,N]

Rate of cylinder pressure rise (kPa/deg)

$dP\theta\,[720, N] = (P\theta_{n-2} - 8 \times P\theta_{n-1} + 8 \times P\theta_{n+1} - P\theta_{n+2}) / (12 \times res)$
When the resolution is 1 CA, the calculation is made as shown below.
When n = 1 or 2, $(P\theta_{n-2}, P\theta_{n-1}) = (P\theta_{001}, P\theta_{001})$
When n = 719 or 720, $(P\theta_{n+1}, P\theta_{n+2}) = (P\theta_{720}, P\theta_{720})$

N:	Number of cycles
Pθ:	Cylinder pressure (kPa) after absolute pressure correction (calculated value)
res:	Angular resolution (1, 0.5, 0.25, or 0.1 CA)

13. dPθ ave [720]

Average rate of cylinder pressure rise (kPa/deg)

$dP\theta\ ave[720] = (1 / N) \times \Sigma(dP\theta\ in[720,N])$

N :	Number of cycles
dPθ :	Rate of cylinder pressure rise (kPa/deg) (calculated value)

14. Pmax[N]

Maximum cylinder pressure (kPa)

Pmax[N] = max(Pθ [720,N]) *# max: maximum value*

N :	Number of cycles
Pθ :	Cylinder pressure (kPa) (calculated value)

15. θPmax [N]

Crank angle at maximum cylinder pressure (CA)

θPmax[N] = pos(Pθ [720,N]) *# pos: crank angle at max. cylinder pressure*

N :	Number of cycles
Pθ :	Cylinder pressure (kPa) (calculated value)

16. θPmax_ave

Averaged crank angle at maximum cylinder pressure (CA)

θPmax_ave = (1 / N) × Σ(θPmax [N])

N :	Number of cycles
θPmax :	Crank angle at maximum cylinder pressure (CA) (calculated value)

17. Pmax_ave

Averaged maximum cylinder pressure (kPa)

Pmax_ave = (1 / N) × Σ(Pmax [N])

N :	Number of cycles
Pmax :	Maximum cylinder pressure (kPa) (calculated value)

18. Pmax_std

Standard deviation of maximum cylinder pressure (kPa)

Pmax_std = sqrt((1 / (N–1)) × Σ(Pmax [N] – Pmax_ave)^2) *# sqrt: square root*

N :	Number of cycles
Pmax :	Maximum cylinder pressure (kPa) (calculated value)
Pmax_ave :	Averaged maximum cylinder pressure (kPa) (calculated value)

19. Pmax_cov

Rate of change (%) in maximum cylinder pressure

Pmax_cov = (Pmax_std / Pmax_ave) × 100

Pmax_std :	Standard deviation of the max. cylinder pressure (kPa) (calculated value)
Pmax_ave :	Averaged max. cylinder pressure (kPa) (calculated value)

20. Pmax_Cy[N]

Averaged maximum cylinder pressure of all cylinders (kPa)

Pmax_Cy[N] = (1 / Cy) × Σ(Pmax [Cy, N])

Cy :	Number of cylinders
N:	Number of cycles
Pmax :	Maximum cylinder pressure (kPa) (calculated value)

21. Pmax_Cy_ave

Averaged maximum cylinder pressure of all cycles and cylinders (kPa)

$Pmax\_Cy\_ave = (1 / N) \times \Sigma(Pmax\_Cy [N])$

N : Number of cycles
Pmax_Cy : Averaged maximum cylinder pressure of all cylinders (kPa) (calculated value)

22. θPmax_Cy [N]

Averaged crank angle at maximum cylinder pressure of all cylinders (CA)

$\theta Pmax\_Cy[N] = (1 / Cy) \times \Sigma(\theta Pmax [Cy, N])$

Cy: Number of cylinders
N : Number of cycles
θPmax : Crank angle at maximum cylinder pressure (CA) (calculated value)

23. θPmax_Cy_ave

Averaged crank angle at maximum cylinder pressure of all cycles and cylinders (CA)

$\theta Pmax\_Cy\_ave = (1 / N) \times \Sigma(\theta Pmax\_Cy [N])$

N : Number of cycles
θPmax_Cy : Averaged crank angle at maximum cylinder pressure of all cylinders (CA) (calculated value)

24. dPmax[N]

Maximum rate of cylinder pressure rise (kPa/deg)

$dPmax[N] = max(dP\theta [720,N])$ # *max: maximum value*

N : Number of cycles
dPθ : Rate of cylinder pressure rise (kPa/deg) (calculated value)

25. θdPmax[N]

Crank angle at maximum rate of cylinder pressure rise (CA)

$\theta dPmax[N] = pos(dP\theta [720,N])$
pos: crank angle at the maximum rate of cylinder pressure rise

N : Number of cycles
dPθ : Rate of cylinder pressure rise (kPa/deg) (calculated value)

26. θdPmax_ave

Averaged crank angle at maximum rate of cylinder pressure rise (CA)

$\theta dPmax\_ave = (1 / N) \times \Sigma(\theta dPmax [N])$

N : Number of cycles
dPθmax : Crank angle at maximum rate of cylinder pressure rise (CA) (calculated value)

27. dPmax_ave

Averaged maximum rate of cylinder pressure rise (kPa/deg)

$dPmax\_ave = (1 / N) \times \Sigma(dPmax [N])$

N: Number of cycles
dPmax : Maximum rate of cylinder pressure rise (kPa/deg) (calculated value)

28. dPmax_std

Standard deviation of maximum rate of cylinder pressure rise (kPa/deg)

$dPmax\_std = sqrt((1 / (N-1)) \times \Sigma(dPmax [N] - dPmax\_ave)^2)$ *# sqrt: square root*

N: Number of cycles
dPmax : Maximum rate of cylinder pressure rise (kPa/deg) (calculated value)
dPmax_ave : Averaged maximum rate of cylinder pressure rise (kPa/deg) (calculated value)

29. dPmax_cov

Rate of change (%) in maximum cylinder pressure rise

$dPmax\_cov = (dPmax\_std / dPmax\_ave) \times 100$

dPmax_std : Standard deviation of maximum rate of cylinder pressure rise (kPa/deg) (calculated value)
dPmax_ave : Averaged maximum rate of cylinder pressure rise (kPa/deg) (calculated value)

30. dPmax_Cy[N]

Averaged maximum rate of cylinder pressure rise of all cylinders (kPa/deg)

$dPmax\_Cy[N] = (1 / Cy) \times \Sigma(dPmax [Cy, N])$

Cy : Number of cylinders
N: Number of cycles
dPmax : Maximum rate of cylinder pressure rise (kPa/deg) (calculated value)

31. dPmax_Cy_ave

Averaged maximum rate of cylinder pressure rise of all cycles and cylinders (kPa/deg)

$dPmax\_Cy\_ave = (1 / N) \times \Sigma(dPmax\_Cy [N])$

N : Number of cycles
dPmax_Cy : Averaged maximum rate of cylinder pressure rise of all cylinders (kPa/deg) (calculated value)

32. θdPmax_Cy [N]

Averaged crank angle at maximum rate of cylinder pressure rise of all cylinders (CA)

$\theta dPmax\_Cy[N] = (1 / Cy) \times \Sigma(\theta dPmax [Cy, N])$

Cy: Number of cylinders
N : Number of cycles
θdPmax : Crank angle at maximum rate of cylinder pressure rise (CA) (calculated value)

33. θdPmax_Cy_ave

Averaged crank angle at maximum rate of cylinder pressure rise of all cycles and cylinders (CA)

$\theta dPmax\_Cy\_ave = (1 / N) \times \Sigma(\theta dPmax\_Cy [N])$

N : Number of cycles
θdPmax_Cy : Averaged crank angle at maximum rate of cylinder pressure rise of all cylinders (CA) (calculated value)

34. Wpower [N]

Compression/expansion work (J)

$\Delta V = abs(V\theta_i - V\theta_{i+1})$ *# abs: absolute value*
$A[N] = \Sigma (0.5 \times (P\theta_i + P\theta_{i+1}) \times 1000.0 \times \Delta V)$ $\theta = -180$ to -1
$B[N] = \Sigma (0.5 \times (P\theta_i + P\theta_{i+1}) \times 1000.0 \times \Delta V)$ $\theta = 0$ to 179
Wpower[N] = B[N] – A[N]
For a 2-cycle engine, when θ = 179, $P\theta_{i+1}$ is $P\theta_i$, and $V\theta_{i+1}$ is $V\theta_{-180}$.

N : Number of cycles
Vθ : Piston displacement (m^3) (calculated value)
Pθ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

35. Wpump[N]

Pumping loss (J)

$\Delta V = abs(V\theta_i - V\theta i+1)$ *# abs: absolute value*
$C[N] = \Sigma (0.5 \times (P\theta_i + P\theta_{i+1}) \times 1000.0 \times \Delta V)$ $\theta = 180$ to 359
$D[N] = \Sigma (0.5 \times (P\theta_i + P\theta_{i+1}) \times 1000.0 \times \Delta V)$ $\theta = -360$ to -181
Wpump[N] = C[N] – D[N]
When θ = 359, $P\theta_{i+1}$ is $P\theta_i$, and $V\theta_{i+1}$ is $V\theta_{-360}$.
Wpump[N] is zero for 2-cycle engines.

N : Number of cycles
Vθ : Piston displacement (m^3) (calculated value)
Pθ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

36. Vst

Piston displacement (m^3)

$Vst = (pi / 4) \times B^2 \times S$

pi : The circular constant
B : Bore (m) (manually input)
S : Stroke length (m) (manually input)

37. NMEP[N]

NMEP (kPa)

NMEP[N] = (Wpower [N] / 1000.0 – Wpump[N] / 1000.0) / Vst

N : Number of cycles
Wpower : Compression/expansion work (J) (calculated value)
Wpump : Pumping loss (J) (calculated value)
Vst : Piston displacement (m^3) (calculated value)

38. NMEP_ave

Averaged NMEP (kPa)

NMEP_ave = (1 / N) × Σ(NMEP [N])

N : Number of cycles
NMEP : NMEP (kPa) (calculated value)

39. NMEP_std

Standard deviation of NMEP (kPa)

NMEP_std = sqrt((1 / (N–1)) × Σ(NMEP [N] – NMEP_ave)^2) *# sqrt: square root*

N : Number of cycles
NMEP : NMEP (kPa) (calculated value)
NMEP_ave : Averaged NMEP (kPa) (calculated value)

40. NMEP_cov

Rate of change in NMEP (%)

NMEP_cov = (NMEP_std / NMEP_ave) × 100

NMEP_std : Standard deviation of NMEP (kPa) (calculated value)
NMEP_ave : Averaged NMEP (kPa) (calculated value)

41. NMEP_Cy[N]

Averaged NMEP of all cylinders (kPa)

NMEP_Cy[N] = (1 / Cy) × Σ(NMEP [Cy, N])

Cy: Number of cylinders
N : Number of cycles
NMEP : NMEP (kPa) (calculated value)

42. NMEP_Cy_ave

Averaged NMEP of all cycles and cylinders (kPa)

NMEP_Cy_ave = (1 / N) × Σ(NMEP_Cy [N])

N : Number of cycles
NMEP_Cy : Averaged NMEP of all cylinders (kPa) (calculated value)

43. IMEP[N]

IMEP (kPa)

IMEP[N] = (Wpower [N] / 1000.0) / Vst

N : Number of cycles
Wpower : Compression/expansion work (J) (calculated value)
Vst : Piston displacement (m^3) (calculated value)

44. IMEP_ave

Averaged IMEP (kPa)

IMEP_ave = (1 / N) × Σ(IMEP [N])

N : Number of cycles
IMEP : IMEP (kPa) (calculated value)

45. IMEP_std

Standard deviation of IMEP (kPa)

$IMEP\_std = sqrt((1 / (N-1)) \times \Sigma(IMEP [N] - IMEP\_ave)^2)$ *# sqrt: square root*

N : Number of cycles
IMEP : IMEP (kPa) (calculated value)
IMEP_ave : Averaged IMEP (kPa) (calculated value)

46. IMEP_cov

Rate of change in IMEP (%)

$IMEP\_cov = (IMEP\_std / IMEP\_ave) \times 100$

IMEP_std : Standard deviation of IMEP (kPa) (calculated value)
IMEP_ave : Averaged IMEP (kPa) (calculated value)

47. IMEP_min

Minimum value of IMEP (kPa)

$IMEP\_min = min (IMEP[N])$ *# min: minimum value*

N : Number of cycles
IMEP : IMEP (kPa) (calculated value)

48. IMEP_LNV

LNV of IMEP (%)

$IMEP\_LNV = (IMEP\_min / IMEP\_ave) \times 100$

IMEP_min : Minimum value of IMEP (kPa)
IMEP_ave : Averaged IMEP (kPa) (calculated value)

49. R_misfire

Rate of misfire (%)

$R\_misfire = (count(IMEP[N] < L) / N) \times 100$
 # count: calculates the number of data that are applicable to the specified conditions

N : Number of cycles
L : Value for judging misfire (kPa) (manually input)
IMEP : IMEP (kPa) (calculated value)

50. IMEP_Cy[N]

Averaged IMEP of all cylinders (kPa)

$IMEP\_Cy[N] = (1 / Cy) \times \Sigma(IMEP [Cy, N])$

Cy: Number of cylinders
N : Number of cycles
NMEP : IMEP (kPa) (calculated value)

51. IMEP_Cy_ave

Averaged IMEP of all cycles and cylinders (kPa)

$IMEP\_Cy\_ave = (1 / N) \times \Sigma(IMEP\_Cy [N])$

N : Number of cycles
IMEP_Cy : Averaged IMEP of all cylinders (kPa) (calculated value)

52. PMEP[N]

PMEP (kPa)

PMEP[N] = ((–1 × Wpump [N]) / 1000.0) / Vst

N :	Number of cycles
Wpump :	Pumping loss (J) (calculated value)
Vst :	Piston displacement (m^3) (calculated value)

53. PMEP_ave

Averaged PMEP (kPa)

PMEP_ave = (1 / N) × Σ(PMEP [N])

N :	Number of cycles
PMEP :	PMEP (kPa) (calculated value)

54. PMEP_std

Standard deviation of PMEP (kPa)

PMEP_std = sqrt((1 / (N–1)) × Σ(PMEP[N] – PMEP_ave)^2) *# sqrt: square root*

N :	Number of cycles
PMEP :	PMEP (kPa) (calculated value)
PMEP_ave :	Averaged PMEP (kPa) (calculated value)

55. PMEP_cov

Rate of change in PMEP (%)

PMEP_cov = (PMEP_std / PMEP_ave) × 100

PMEP_std :	Standard deviation of PMEP (kPa) (calculated value)
PMEP_ave :	Averaged PMEP (kPa) (calculated value)

56. PMEP_Cy[N]

Averaged PMEP of all cylinders (kPa)

PMEP[N] = (1 / Cy) × Σ(IMEP [Cy, N])

Cy:	Number of cylinders
N :	Number of cycles
NMEP :	PMEP (kPa) (calculated value)

57. PMEP_Cy_ave

Averaged PMEP of all cycles and cylinders (kPa)

PMEP_Cy_ave = (1 / N) × Σ(PMEP_Cy [N])

N :	Number of cycles
PMEP_Cy :	Averaged PMEP of all cylinders (kPa) (calculated value)

58. Tθ [720,N]

Cylinder gas temperature (°C)

(1) Go2

Oxygen requirement (m^3) per 1 m^3 fuel at 0° C, 1 atomsphric pressure

Go2 = 2 × rCH4 + 3.5 × rC2H6 + 5 × rC3H8 + 6.5 × rC4H10

rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rC4H10:	Composition ratio of butane (%) (manually input) (= composition ratio of isobutane + composition ratio of n-butane)

(2) Gex

Exhaust gas (m^3) per 1 m^3 fuel at 0° C, 1 atomsphric pressure

Gex = (1 + 2) × rCH4 + (2 + 3) × rC2H6 + (3 + 4) × rC3H8 + (4 + 5) × rC4H10

rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rC4H10:	Composition ratio of butane (%) (manually input) (= composition ratio of isobutane + composition ratio of n-butane)

(3) Ao

Theoretical air (m^3) per 1 m^3 fuel at 0° C, 1 atomsphric pressure

Ao = (Go2 / 20.948) × 100

Go2:	Oxygen requirement (m^3) (calculated value)
20.948:	Oxygen concentration (%) in the air (manually input)

(4) Go

Theoretical exhaust gas (m^3) per 1 m^3 fuel at 0° C, 1 atomsphric pressure

Go = ((79.052 / 100) × Ao) + Gex

79.052:	Concentration of elements other than oxygen (nitrogen) in the air (%) (manually input)
Ao:	Theoretical air (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
Gex:	Exhaust gas (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)

(5) Wg

Amount of water produced (m^3) per 1 m^3 fuel

Wg = 2 × rCH4 +3 × rC2H6 + 4 × rC3H8 + 5 × rC4H10

rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rC4H10:	Composition ratio of butane (%) (manually input) (= composition ratio of isobutane + composition ratio of n-butane)

(6) God

Theoretical volume of dry exhaust gas (m^3) per 1 m^3 fuel at 0° C, 1 atomsphric pressure

God = Go − Wg

Go:	Theoretical exhaust gas (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
Wg:	Amount of water produced (m^3) (calculated value)

(7) λ

Excess air factor

λ = (God × EXTo2 + 100 × Go2 − Ao × EXTo2) / ((20.948 − EXTo2) × Ao)

When concentration of oxygen remaining in exhaust gas is set to be measured and used in calculations:
λ[N] = (God × EXTo2_ave[N] + 100 × Go2 − Ao × EXTo2_ave[N]) / ((20.948 − EXTo2_ave[N]) × Ao)
λ_ave = ave(λ[N]) *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

God:	Theoretical volume of dry exhaust gas (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
EXTo2:	Concentration of oxygen remaining in exhaust gas (%) (manually input) Uses EXTo2_ave[N] (average concentration of oxygen remaining in exhaust at each cycle) when concentration of oxygen remaining in exhaust gas is set to be measured and used in calculations. EXTo2_ave[N] = ave(EXTo2[720,N]) *# ave: average value*
Go2:	Oxygen requirement (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
Ao:	Theoretical air (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
20.948:	Oxygen concentration (%) in the air (manually input)

(8) Ac

Intake air volume (m^3/h) relative to the fuel consumption

Ac = λ × Ao × Fc

When concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations:
Ac[N] = λ[N] × Ao × Fc_ave[N]
Ac_ave = ave(Ac[N]) *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

λ:	Excess air factor (calculated value) Uses λ[N] (Excess air factor at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.
Ao:	Theoretical air (m^3) (at 0° C, 1 atomsphric pressure) (calculated value)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) *# ave: average value*

(9) Gin

Intake fuel-air mixture volume (m^3/h)

Gin = (Fc + Ac) × ((273.16 + Td) / 273.16) × (101.325 / Pa)

When concentration of oxygen remaining in exhaust gas, fuel consumption, intake manifold temperature, and intake manifold pressure are set to be measured and used in calculations:
Gin[N] = (Fc_ave[N] + Ac[N]) × ((273.16 + Td_ave[N]) / 273.16) × (101.325 / Pitk_ave[N])
Gin_ave = ave(Gin[N]) # *ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

Fc:	Fuel consumption (m^3/h) (manually input) Uses Fc_ave[N] (average fuel consumption at each cycle, calculated value) when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) # *ave: average value*
Ac:	Intake air volume (m^3/h) (calculated) Uses Ac[N] (average intake air volume at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.
273.16:	Correction value for absolute temperature
Td:	Atmospheric temperature (°C) (manually input) Uses Td_ave[N] (average intake manifold temperature at each cycle, calculated value) when intake manifold temperature is set to be measured and used in calculations. Td_ave[N] = ave(Td[720,N]) # *ave: average value*
101.325:	1 atmosphere in kilopascals (kPa)
Pa:	Atmospheric pressure (kPa) (manually input) Uses Pitk_ave[N] (average intake manifold pressure at each cycle, calculated value) when intake manifold pressure is set to be measured and used in calculations.

5

Equations

(10) ηv

Volumetric efficiency (%)

ηv = (Gin / ((1 / En_cyl) × Ne × Sn × Vst × 60)) × 100

When concentration of oxygen remaining in exhaust gas, fuel consumption, intake manifold tempersture, and intake manifold pressure are set to be measured and used in calculations:
ηv[N] = (Gin[N] / ((1 / En_cyl) × Ne_ave[N] × Sn × Vst × 60)) × 100
ηv_ave = ave(ηv[N]) # *ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

En_cyl:	Engine cycle 4-cycle engine: En_cyl = 2 2-cycle engine: En_cyl = 1
Gin:	Intake fuel-air mixture volume (m^3/h) (calculated value) Uses Gin[N] (intake fuel-air mixture volume at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas, fuel consumption, intake manifold temperature, and intake manifold pressure are set to be measured and used in calculations.
Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) # *ave: average value*
Sn:	Number of cylinders (manually input)
Vst:	Piston displacement (m^3)

(11) Cv

Specific gravity of fuel gas

Cv = 0.554 × rCH4 + 1.0446 × rC2H6 + 1.5477 × rC3H8 + 2.0601 × rIC4H10 + 2.0722 × rNC4H10

rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rIC4H10:	Composition ratio of isobutane (%) (manually input)
rNC4H10:	Composition ratio of normal butane (%) (manually input) rC4H10 = rIC4H10 + rNC4H10
0.554:	Specific gravity of methane relative to the air
1.0446:	Specific gravity of ethane relative to the air
1.5477:	Specific gravity of propane relative to the air
2.0601:	Specific gravity of isobutane relative to the air
2.0722:	Specific gravity of normal butane relative to the air

(12) Ga, Gf

Ga: Mass of intake air (kg)
Gf: Mass of intake fuel (kg)

Ga = (Ac / ((1 / En_cyl) × Ne × Sn × 60)) × 1.2928
Gf = (Fc / ((1 / En_cyl) × Ne × Sn × 60)) × Cv × 1.2928

When concentration of oxygen remaining in exhaust gas, fuel consumption, and rpm are set to be measured and used in calculations:
Ga[N] = (Ac[N] / ((1 / En_cyl) × Ne_ave[N] × Sn × 60)) × 1.2928
Gf[N] = (Fc_ave[N] / ((1 / En_cyl) × Ne_ave[N] × Sn × 60)) × Cv × 1.2928

Ac: Intake air volume (m^3/h) (calculated)
Uses Ac[N] (average intake air volume at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.

Fc: Fuel consumption (m^3/h) (manually input)
Uses Fc_ave[N] (average fuel consumption at each cycle, calculated value) when fuel consumption is set to be measured and used in calculations.
Fc_ave[N] = ave(Fc[720,N]) *# ave: average value*

En_cyl: Engine cycle
4-cycle engine: En_cyl = 2
2-cycle engine: En_cyl = 1

Ne: Revolutions per minute (rpm) (manually input)
Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations.
Ne_ave[N] = ave(Ne[720,N]) *# ave: average value*

Sn: Number of cylinders (manually input)

60: Factor for conversion from minutes to hours

Cv: Specific gravity of fuel gas (calculated value)

1.2928: Density of air (kg/m^3) (0°C, 1 atmosphere)

(13) G

Mass of intake gas mixture (kg)

G = Ga + Gf

When concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations:
G[N] = Ga[N] + Gf[N]

Ga: Mass of intake air (kg) (calculated value)
Uses Ga[N] (mass of intake air at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.

Gf: Mass of intake fuel (kg) (calculated value)
Uses Gf[N] (mass of intake fuel at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.

(14) R

Gas mixture constant (Jkg.K)

RCH4 = (1 × RCO2 + 2 × RH2O + 2 × (λ – 1) × RO2 + 2 × Nr × λ × RN2) / (1 + 2 + 2 × (λ – 1) + 2 × Nr × λ)

RCH6 = (2 × RCO2 + 3 × RH2O + 3.5 × (λ – 1) × RO2 + 3.5 × Nr × λ × RN2) / (2 + 3 + 3.5 × (λ – 1) + 3.5 × Nr × λ)

RC3H8 = (3 × RCO2 + 4 × RH2O + 5 × (λ – 1) × RO2 + 5 × Nr × λ× RN2) / (3 + 4 + 5 × (λ – 1) + 5 × Nr × λ)

RC4H10 = (4 × RCO2 + 5 × RH2O + 6.5 × (λ – 1) × RO2 + 6.5 × Nr × λ × RN2) / (4 + 5 + 6.5 × (λ – 1) + 6.5 × Nr × λ)

R = 1 / ((rCH4 / RCH4) + (rC2H6 / RCH6) + (rC3H8 / RC3H8) + (rC4H10 / RC4H10))

When concentration of oxygen remaining in exhaust gas is set to be measured and used in calculations:

RCH4[N] = (1 × RCO2 + 2 × RH2O + 2 × (λ[N] – 1) × RO2 + 2 × Nr × λ[N] × RN2) / (1 + 2 + 2 × (λ[N] – 1) + 2 × Nr × λ[N])

RC2H6[N] = (2 × RCO2 + 3 × RH2O + 3.5 × (λ[N] – 1) × RO2 + 3.5 × Nr × λ[N] × RN2) / (2 + 3 + 3.5 × (λ[N] – 1) + 3.5 × Nr × λ[N])

RC3H8[N] = (3 × RCO2 + 4 × RH2O + 5 × (λ[N] – 1) × RO2 + 5 × Nr × λ[N]× RN2) / (3 + 4 + 5 × (λ[N] – 1) + 5 × Nr × λ[N])

RC4H10[N] = (4 × RCO2 + 5 × RH2O + 6.5 × (λ[N] – 1) × RO2 + 6.5 × Nr × λ[N] × RN2) / (4 + 5 + 6.5 × (λ[N] – 1) + 6.5 × Nr × λ[N])

R[N] = 1 / ((rCH4 / RCH4[N]) + (rC2H6 / RC2H6[N]) + (rC3H8 / RC3H8[N]) + (rC4H10 / RC4H10[N]))

RCO2:	8314.3 / 43.9893 (J/kg.K)
RH2O:	8314.3 / 18.010565 (J/kg.K)
RO2:	8314.3 / 31.98983 (J/kg.K)
RN2:	8314.3 / 28.006148 (J/kg.K)
Nr:	Ratio of nitrogen and oxygen in the air = 79.052 / 20.948
λ:	Excess air factor (calculated value) Uses λ[N] (Excess air factor at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.
rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rC4H10:	Composition ratio of butane (%) (manually input) (= composition ratio of isobutane + composition ratio of n-butane)

(15) Tθ[720, N]

Cylinder gas temperature (°C)

$T\theta[720,N] = (P\theta[720,N] \times 1000 \times V\theta[720]) / (G \times R) - 273.16$

When concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations:
$T\theta[720,N] = (P\theta[720,N] \times 1000 \times V\theta[720]) / (G[N] \times R[N]) - 273.16$

Pθ: Cylinder pressure (kPa) after absolute pressure correction (calculated value)
Vθ: Piston displacement (m^3) (calculated value)
G: Mass of intake gas mixture (kg) (calculated value)
Uses G[N] (mass of intake gas mixture at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas, fuel consumption, and rpm are set to be measured and used in calculations.
R: Gas mixture constant (J/kg.K) (calculated value)
Uses R[N] (gas mixture constant at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.

59. Tθ ave[720]

Average cylinder gas temperature (°C)

$T\theta\ ave[720] = (1 / N) \times \Sigma(T\theta\ [720,N])$

N : Number of cycles
Tθ : Cylinder gas temperature (°C) (calculated value)

60. Tmax[N]

Maximum cylinder gas temperature (°C)

$Tmax[N] = max(T\theta\ [720,N])$ *# max: maximum value*

N : Number of cycles
Tθ : Cylinder gas temperature (°C) (calculated value)

61. θTmax[N]

Crank angle (CA) at maximum cylinder gas temperature

$\theta Tmax[N] = pos(T\theta\ [720,N])$ *# pos: crank angle at the maximum cylinder gas temperature*

N : Number of cycles
Tθ : Cylinder gas temperature (°C) (calculated value)

62. Tmax_ave

Averaged maximum cylinder gas temperature (°C)

$Tmax\_ave = (1 / N) \times \Sigma(Tmax\ [N])$

N : Number of cycles
Tmax : Maximum cylinder gas temperature (°C) (calculated value)

63. Tmax_std

Standard deviation of maximum cylinder gas temperature (°C)

$Tmax\_std = sqrt((1 / (N-1)) \times \Sigma(Tmax[N] - Tmax\_ave)^2)$ *# sqrt: square root*

N :	Number of cycles
Tmax :	Maximum cylinder gas temperature (°C) (calculated value)
Tmax_ave :	Averaged maximum cylinder gas temperature (°C) (calculated value)

64. Tmax_cov

Rate of change in maximum cylinder gas temperature (%)

$Tmax\_cov = (Tmax\_std / Tmax\_ave) \times 100$

Tmax_std :	Standard deviation of maximum cylinder gas temperature (°C) (calculated value)
Tmax_ave :	Averaged maximum cylinder gas temperature (°C) (calculated value)

65. dQθ[720,N]

Rate of heat release (J/deg)

(1) κθ[720,N]

Ratio of specific heat

$T = T\theta[360,N] + 273.16$

$\kappa\theta[720,N] = 1.4373 - 1.318 \times 10^{-4} \times T + 3.12 \times 10^{-8} \times T^2 - 4.8 \times 10^{-2} / \lambda$

When concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations:

$T = T\theta[360,N] + 273.16$

$\kappa\theta[720,N] = 1.4373 - 1.318 \times 10^{-4} \times T + 3.12 \times 10^{-8} \times T^2 - 4.8 \times 10^{-2} / \lambda[N]$

Tθ :	Cylinder gas temperature (°C) (calculated value)
λ:	Excess air factor (calculated value) Uses λ[N] (Excess air factor at each cycle, calculated value) when concentration of oxygen remaining in exhaust gas and fuel consumption are set to be measured and used in calculations.

(2) κθ ave[720]

Average ratio of specific heat

$\kappa\theta\ ave[720] = (1 / N) \times \Sigma(\kappa\theta[720,N])$

N :	Number of cycles
κθ :	Ratio of specific heat (calculated value)

(3) dQ θ [720, N]

Rate of heat release (J/deg)

$dQ\theta[720,N] = (\kappa\theta[720,N] / (\kappa\theta[720,N] - 1)) \times P\theta[720,N] \times 1000.0 \times dV\theta[720]$
$+ (1 / (\kappa\theta[720,N] - 1)) \times dP\theta[720,N] \times 1000.0 \times V\theta[720]$

N :	Number of cycles
κθ :	Ratio of specific heat (calculated value)
Pθ :	Cylinder pressure (kPa) after absolute pressure correction (calculated value)
Vθ :	Piston displacement (m^3) (calculated value)
dPθ :	Rate of cylinder pressure rise (kPa/deg) (calculated value)

66. dQθ ave [720]

Average rate of heat release (J/deg)

$dQ\theta\ ave[720] = (1 / N) \times \Sigma(dQ\theta\ [720,N])$

N :	Number of cycles
dQθ :	Rate of heat release (J/deg) (calculated value)

67. dQmax[N]

Maximum rate of heat release (J/deg)

$dQmax[N] = max(dQ\theta\ [720,N])$

 # max: Indicates the maximum value within the manually input search range of the maximum rate of release.

N :	Number of cycles
dQθ :	Rate of heat release (J/deg) (calculated value)

68. θdQmax[N]

Crank angle at maximum rate of heat release (CA)

$\theta dQmax[N] = pos(dQ\theta\ [720,N])$ *# pos: crank angle at maximum rate of heat release*

N :	Number of cycles
dQθ :	Rate of heat release (J/deg) (calculated value)

69. θdQmax_ave

Averaged crank angle at maximum rate of heat release (CA)

$\theta dQmax\_ave = (1 / N) \times \Sigma(\theta dQmax\ [N])$

N :	Number of cycles
θdQmax :	Crank angle at maximum rate of heat release (CA) (calculated value)

70. dQmax_ave

Averaged maximum rate of heat release (J/deg)

$dQmax\_ave = (1 / N) \times \Sigma(dQmax\ [N])$

N:	Number of cycles
dQmax :	Maximum rate of heat release (J/deg) (calculated value)

71. dQmax_std

Standard deviation of maximum rate of heat release (J/deg)

$dQmax\_std = sqrt((1 / (N-1)) \times \Sigma(dQmax\ [N] - dQmax\_ave)^2)$ *# sqrt: square root*

N:	Number of cycles
dQmax :	Maximum rate of heat release (J/deg) (calculated value)
dQmax_ave :	Averaged maximum rate of heat release (J/deg) (calculated value)

72. dQmax_cov

Rate of change (%) in maximum rate of heat release

$dQmax\_cov = (dQmax\_std / dQmax\_ave) \times 100$

dQmax_std :	Standard deviation of the maximum rate of heat release (J/deg) (calculated value)
dQmax_ave :	Averaged maximum rate of heat release (J/deg) (calculated value)

73. Qθ [720,N]

Amount of heat release (J)

$Q\theta\ [720,N] = \Sigma\ (dQ\theta) \times res$
Cumulative sum from point a to θ. dQθ is zero from 0 to point a.

N :	Number of cycles
dQθ :	Rate of heat release (J/deg) (calculated value)
res :	Angular resolution (1, 0.5, 0.25, or 0.1 CA)
a :	Start point of combustion. Crank angle (CA) at which the value of dQθ is changed to a positive value immediately before Qmax (calculated value) (value automatically searched for, starting from dQmax in the direction of decreasing angles) When manually input, the setting value is assumed to be point "a."

74. Qθ ave [720]

Average amount of heat release (J)

$Q\theta\ ave[720] = (1 / N) \times \Sigma(Q\theta\ [720,N])$

N :	Number of cycles
Qθ :	Amount of heat release (J) (calculated value)

75. Qmax [N]

Maximum amount of heat release (J)

$Qmax[N] = max(Q\theta\ [720,N])$ # *max: maximum value*

N :	Number of cycles
Qθ :	Amount of heat release (J) (calculated value)

76. θQmax [N]

Crank angle (CA) at maximum amount of heat release

$\theta Qmax[N] = pos(Q\theta\ [720,N])$ # *pos: crank angle at the maximum amount of heat release*

N :	Number of cycles
Qθ :	Amount of heat release (J) (calculated value)

77. θQmax_ave

Averaged crank angle at maximum amount of heat release (CA)

$\theta Qmax\_ave = (1 / N) \times \Sigma(\theta Qmax\ [N])$

N :	Number of cycles
θQmax :	Crank angle at maximum amount of heat release (CA) (calculated value)

78. Qmax_ave

Averaged maximum amount of heat release (J)

$Qmax\_ave = (1 / N) \times \Sigma(Qmax\ [N])$

N :	Number of cycles
Qmax :	Maximum amount of heat release (J) (calculated value)

79. Qmax_std

Standard deviation of maximum amount of heat release (J)

Qmax_std = sqrt((1 / (N–1)) × Σ(Qmax [N] – Qmax_ave)^2) # *sqrt: square root*

N :	Number of cycles
Qmax :	Maximum amount of heat release (J) (calculated value)
Qmax_ave :	Averaged maximum amount of heat release (J) (calculated value)

80. Qmax_cov

Rate of change (%) in maximum amount of heat release

Qmax_cov = (Qmax_std / Qmax_ave) × 100

Qmax_std :	Standard deviation of maximum amount of heat release (J) (calculated value)
Qmax_ave :	Averaged maximum amount of heat release (J) (calculated value)

81. Qab

Amount of heat release during the combustion period (J)

Qab[N] = Σ (dQθ [720,N]) × res
The sum from point a to point b at each cycle

N :	Number of cycles
dQθ :	Rate of heat release (J/deg) (calculated value)
res :	Angular resolution (1, 0.5, 0.25, or 0.1 CA)
a :	Start point of combustion. Crank angle (CA) at which the value of dQθ is changed to a positive value immediately before dQmax (calculated value) When manually input, the setting value is assumed to be point “a.”
b :	End point of combustion. Crank angle (CA) at which the value of dQθ is changed to a negative value immediately after dQmax (calculated value) When manually input, the setting value is assumed to be point “b.”

82. Qab_ave

Average amount of heat release during the combustion period (J)

Qab_ave = (1 / N) × Qab [N]

N :	Number of cycles
Qab :	Amount of heat release during the combustion period (J) (calculated value)

83. RHθ [720,N]

Combustion mass rate (%)

RHθ [720, N] = Qθ [720,N] / Qab[N]

N :	Number of cycles
Qθ :	Amount of heat release (J) (calculated value)
Qab :	The calculated sum (J) from point a to point b at each cycle

84. RHθ ave [720]

Average combustion mass rate (%)

$RH\theta\ ave[720] = (1 / N) \times \Sigma(RH\theta\ [720,N])$

N : Number of cycles
RHθ : Combustion mass rate (%) (calculated value)

85. θRH[N]

Crank angle at combustion mass rate N1 % (CA)
(the crank angle such that the combustion mass rate is N1 %)

θRH[N] = floor(round(RHθ[720,N]), ratio)
 # floor: the angle whereby RHθ is greater than ratio (depending on the angular resolution)
 # round: round to 1 digit after the decimal place

N : Number of cycles
RHθ : Combustion mass rate (%) (calculated value)
ratio : Ratio for judging angle of combustion mass rate N1 % (%) (manually input)

86. θRH_ave

Averaged angle at combustion mass rate N1 % (CA)

$\theta RH\_ave = (1 / N) \times \Sigma(\theta RH\ [N])$

N : Number of cycles
θRH : Angle at combustion mass rate N1 % (CA) (calculated value)

87. θRH_std

Standard deviation of angle at combustion mass rate N1 % (CA)

$\theta RH\_std = sqrt((1 / (N - 1)) \times \Sigma(\theta RH\ [N] - \theta RH\_ave)^2)$ *# sqrt: square root*

N: Number of cycles
θRH : Angle at combustion mass rate N1 % (CA) (calculated value)
θRH_ave : Averaged angle at combustion mass rate N1 % (CA) (calculated value)

88. θRH_cov

Rate of change in angle at combustion mass rate N1 % (CA)

$\theta RH\_cov = (\theta RH\_std / \theta RH\_ave) \times 100$

θRH_std : Standard deviation of angle at combustion mass rate N1 % (CA) (calculated value)
θRH_ave : Averaged angle at combustion mass rate N1 % (CA) (calculated value)

89. θRH2[N]

Crank angle at combustion mass rate N2 % (CA)
(the crank angle such that the combustion mass rate is N2 %)

θRH2[N] = floor(round(RHθ[720,N]), ratio2)

 # floor: the angle whereby RHθ is greater than ratio2 (depending on the angular resolution)
 # round: round to 1 digit after the decimal place

N :	Number of cycles
RHθ :	Combustion mass rate (%) (calculated value)
ratio2 :	Ratio for judging angle of combustion mass rate N2 % (%) (manually input)

90. θRH2_ave

Averaged angle at combustion mass rate N2 % (CA)

θRH2_ave = (1 / N) × Σ(θRH2 [N])

N :	Number of cycles
θRH2 :	Angle at combustion mass rate N2 % (CA) (calculated value)

91. θRH2_std

Standard deviation of angle at combustion mass rate N2 % (CA)

θRH2_std = sqrt((1 / (N – 1)) × Σ(θRH2 [N] – θRH2_ave)^2)   *# sqrt: square root*

N:	Number of cycles
θRH2 :	Angle at combustion mass rate N2 % (CA) (calculated value)
θRH2_ave :	Averaged angle at combustion mass rate N2 % (CA) (calculated value)

92. θRH2_cov

Rate of change in angle at combustion mass rate N2 % (CA)

θRH2_cov = (θRH2_std / θRH2_ave) × 100

θRH2_std :	Standard deviation of angle at combustion mass rate N2 % (CA) (calculated value)
θRH2_ave :	Averaged angle at combustion mass rate N2 % (CA) (calculated value)

93. θRH3[N]

Crank angle at combustion mass rate N3 % (CA)
(the crank angle such that the combustion mass rate is N3 %)

θRH3[N] = floor(round(RHθ[720,N]), ratio3)

 # floor: the angle whereby RHθ is greater than ratio3 (depending on the angular resolution)
 # round: round to 1 digit after the decimal place

N :	Number of cycles
RHθ :	Combustion mass rate (%) (calculated value)
ratio3 :	Ratio for judging angle of combustion mass rate N3 % (%) (manually input)

94. θRH3_ave

Averaged angle at combustion mass rate N3 % (CA)

$\theta RH3\_ave = (1 / N) \times \Sigma(\theta RH3 [N])$

N :	Number of cycles
θRH3 :	Angle at combustion mass rate N3 % (CA) (calculated value)

95. θRH3_std

Standard deviation of angle at combustion mass rate N3 % (CA)

$\theta RH3\_std = sqrt((1 / (N - 1)) \times \Sigma(\theta RH3 [N] - \theta RH3\_ave)^2)$ *# sqrt: square root*

N:	Number of cycles
θRH3 :	Angle at combustion mass rate N3 % (CA) (calculated value)
θRH3_ave :	Averaged angle at combustion mass rate N3 % (CA) (calculated value)

96. θRH3_cov

Rate of change in angle at combustion mass rate N3 % (CA)

$\theta RH3\_cov = (\theta RH3\_std / \theta RH3\_ave) \times 100$

θRH3_std :	Standard deviation of angle at combustion mass rate N3 % (CA) (calculated value)
θRH3_ave :	Averaged angle at combustion mass rate N3 % (CA) (calculated value)

97. Qi

True heat release of gas fuel (J/m^3) at 0° C, 1 atomsphric pressure
This calculation is not performed if manually input settings were specified for use in the parameter setting screen.

$Qi = 4.18605 \times 1000 \times (8670 \times rCH4 + 15380 \times rC2H6 + 22350 \times rC3H8 + 29610 \times rC4H10)$

rCH4:	Composition ratio of methane (%) (manually input)
rC2H6:	Composition ratio of ethane (%) (manually input)
rC3H8:	Composition ratio of propane (%) (manually input)
rC4H10:	Composition ratio of butane (%) (manually input) (= composition ratio of isobutane + composition ratio of n-butane)
4.18605:	4.18605(J) = 1(cal)

98. Qc

Cooling loss (J)

$Qc = ((Qi \times Fc) / ((1 / En\_cyl) \times 60 \times Ne \times Sn)) - Qab\_ave$

When fuel consumption and rpm are set to be measured and used in calculations:
$Qc[N] = ((Qi \times Fc\_ave[N]) / ((1 / En\_cyl) \times 60 \times Ne\_ave[N] \times Sn)) - Qab\_ave$
Qc_ave = ave(Qc [N]) *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

Qi:	True heat release of gas fuel (J/m^3)
Qab_ave:	Average amount of heat release (J) (calculated value)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) # ave: *average value*
Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) *# ave: average value*
Sn:	Number of cylinders (manually input)
60:	Factor for conversion from minutes to hours
En_cyl:	Engine cycle 4-cycle engine: En_cyl = 2 2-cycle engine: En_cyl = 1

99. ηc

Cooling loss ratio (%)

$\eta c = (Qc / ((Qi \times Fc) / ((1 / En\_cyl) \times 60 \times Ne \times Sn))) \times 100$

When fuel consumption and rpm are set to be measured and used in calculations:
$\eta c[N] = (Qc[N] / ((Qi \times Fc\_ave[N]) / ((1 / En\_cyl) \times 60 \times Ne\_ave[N] \times Sn))) \times 100$
ηc_ave = ave(ηc [N]) *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

Qc:	Cooling loss (J) (calculated value) Uses Qc]N] (cooling loss at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.
Qi:	True heat release of gas fuel (J/m^3)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) *# ave: average value*
Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) *# ave: average value*
Sn:	Number of cylinders (manually input)
60:	Factor for conversion from minutes to hours
En_cyl:	Engine cycle 4-cycle engine: En_cyl = 2 2-cycle engine: En_cyl = 1

100. ηe

Brake thermal efficiency (%)

$\eta e = ((PS \times 3600 \times 1000) / (Qi \times Fc)) \times 100$

When fuel consumption is set to be measured and used in calculations:
$\eta e[N] = ((PS \times 3600 \times 1000) / (Qi \times Fc\_ave[N])) \times 100$
$\eta e\_ave = ave(\eta e [N])$ *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

PS:	Engine power (kW) (manually input)
Qi:	True heat release of gas fuel (J/m^3)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) *# ave: average value*

101. ηf

Friction loss (%)

$Pme = (9000 / (Ne \times Vmax \times Sn)) \times PS \times 1.35962 \times 9.80665 \times 0.001$
$Pmf = NMEP\_ave / Pme$
$PSf = ((Ne \times Vmax \times Sn) / (9000 \times 9.80665)) \times Pmf \times 1000$
$\eta f = ((PSf \times 632.4 \times 100) / (Qi \times Fc)) \times 4.18605 \times 1000$

When fuel consumption and rpm are set to be measured and used in calculations:
$Pme = (9000 / (Ne\_ave[N] \times Vmax \times Sn)) \times PS \times 1.35962 \times 9.80665 \times 0.001$
$Pmf = NMEP\_ave - Pme$
$PSf = ((Ne\_ave[N] \times Vmax \times Sn) / (9000 \times 9.80665)) \times Pmf \times 1000$
$\eta f[N] = ((PSf \times 632.4 \times 100) / (Qi \times Fc\_ave[N])) \times 4.18605 \times 1000$
$\eta f\_ave = ave(\eta f[N])$ *# ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) *# ave: average value*
Vmax:	Maximum piston displacement (m^3) (calculated value)
Sn:	Number of cylinders (manually input)
PS:	Engine power (kW) (manually input)
Pme:	Brake mean effective pressure (kPa)
NMEP_ave:	Averaged NMEP (kPa)
Pmf:	Friction mean effective pressure (kPa)
PSf	Friction loss (× 0.7355(kW))
Qi:	True heat release of gas fuel (J/m^3)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) *# ave: average value*

102. Qe

Combustion efficiency (%)

Qe = (Qab_ave × 100) / (Qi × (Fc / ((1 / En_cyl) × Ne × Sn × 60)))

When fuel consumption and rpm are set to be measured and used in calculations:
Qe[N] = (Qab_ave × 100) / (Qi × (Fc_ave[N] / ((1 / En_cyl) × Ne_ave[N] × Sn × 60)))
Qe_ave = ave(Qe [N]) # *ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

Qab_ave:	Average amount of heat release (J) (calculated value)
Qi:	True heat release of gas fuel (J/m^3)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) # *ave: average value*
Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) # *ave: average value*
Sn:	Number of cylinders (manually input)
60:	Factor for conversion from minutes to hours
En_cyl:	Engine cycle 4-cycle engine: En_cyl = 2 2-cycle engine: En_cyl = 1

103. PolYθ [720]

Polytropic index

PolYθ [720] = – ($\log_{10}$(Pθ ave[n–1] / Pθ ave [n]) / $\log_{10}$ (Vθ [n–1] / Vθ [n]))
n = 0 to 719. when n = 0, Polyθ = 1.

Pθ ave :	Average cylinder pressure (kPa)
Vθ :	Piston displacement (m^3)

104. Vmax

Maximum piston displacement (m^3)

When **Clearance volume** is selected on the Parameter Settings screen
Vmax = Vst + Vc
When **Compression ratio** is selected on the Parameter Settings screen
Vmax = Vst + (Vst / (Cr – 1))

Vst :	Piston displacement (m^3)
Vc :	Clearance volume (m^3)
Cr :	Compression ratio (manually input)

105. Dc

Degree of constant volume

$Dc = (1 / Qmax\_ave) \times \Sigma(dQ\theta\ ave[720] \times res \times (1 / ((V\theta[720] / Vmax)^{(\kappa\theta ave[720] - 1)}))$
$/ (1 - ((1 / Cr)^{(\kappa\theta ave[720] - 1)})))$

Σ is the sum from a_ave to b_ave.

Qmax_ave:	Averaged maximum amount of heat release (J)
dQθave:	Average rate of heat release (J/deg) (calculated value)
res:	Angular resolution (manually input)
Vθ :	Piston displacement (m^3) (calculated value)
Vmax:	Maximum piston displacement (m^3) (calculated value)
κθave:	Average ration of specific heat (calculated value)
Cr:	Compression ratio (manually input) Cr = Vmax / Vc: when the clearance volume is specified in the parameter setting screen.

106. ηi

Indicated efficiency (%)

ηi = (NMEP_ave × 1000 × Vst / (Qi × (Fc / ((1 / En_cyl) × Ne × Sn × 60)))) × 100

When fuel consumption and rpm are set to be measured and used in calculations:
ηi[N] = (NMEP_ave × 1000 × Vst / (Qi × (Fc_ave[N] / ((1 / En_cyl) × Ne_ave[N] × Sn × 60)))) × 100
ηi_ave = ave(ηi [N]) # *ave: average value*
(the average value is displayed as a numerical analysis item and saved to a .csv file)

NMEP_ave:	Average NMEP (kPa)
Vst:	Piston displacement (m^3) (calculated value)
Qi:	True heat release of gas fuel (J/m^3)
Fc:	Fuel consumption (m^3/h) (manually input) Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations. Fc_ave[N] = ave(Fc[720,N]) # *ave: average value*
Ne:	Revolutions per minute (rpm) (manually input) Uses Ne_ave[N] (average rpm at each cycle) when rpm is set to be measured and used in calculations. Ne_ave[N] = ave(Ne[720,N]) # *ave: average value*
Sn:	Number of cylinders (manually input)
60:	Factor for conversion from minutes to hours
En_cyl:	Engine cycle 4-cycle engine: En_cyl = 2 2-cycle engine: En_cyl = 1

107. chXθ ave[720]

Other signals (crank angle graph data)

chXθ ave[720] = (1 / N) × Σ(chX[720,N])

N :	Number of cycles
chX :	Measured value of chX

108. chXave[N]

Other signals (cycle graph data)

chXave[N] = ave(chX[720,N]) # *ave: average value*

N : Number of cycles
chX : Measured value of chX

109. a_ave

Average start point of combustion (CA)

a_ave = (1 / N) × Σa[N]

N : Number of cycles
a : Crank angle (CA) at which the value of dQθ is changed to a positive value immediately before dQmax (calculated value)
When manually input, the setting value is assumed to be point “a.”

110. b_ave

Average end point of combustion (CA)

b_ave = (1 / N) × Σb[N]

N : Number of cycles
b : Crank angle (CA) at which the value of dQθ is changed to a negative value immediately after dQmax (calculated value)
When manually input, the setting value is assumed to be point “b.”

6.1 Overview

This function is an add-on for the Engine Combustion Pressure Analysis Package.
This function is only available when used in conjunction with the Engine Combustion Pressure Analysis Package.
With the Monitor Function, you can use your WE7000 series instrument (WE7235, WE7245, WE7271, WE7272, or WE7275) or the DL750 to measure cylinder pressure over given periods of time during motoring or firing, and continuously monitor the measurements. You can also save the resultant data.

- **Monitoring Raw Data (Motoring Data)**
  - Displays one cycle's worth of raw (measured) data before or after TDC correction.
  - If filters were applied, filtered waveforms are displayed.
  - The specified number of cycles of raw (measured) data is acquired, then saved in WVF format.

- **Monitoring Analysis Results (Firing Data)**
  - TDC correction and absolute pressure correction are performed on the data, then analysis results below are displayed according to monitor items that the user selects.

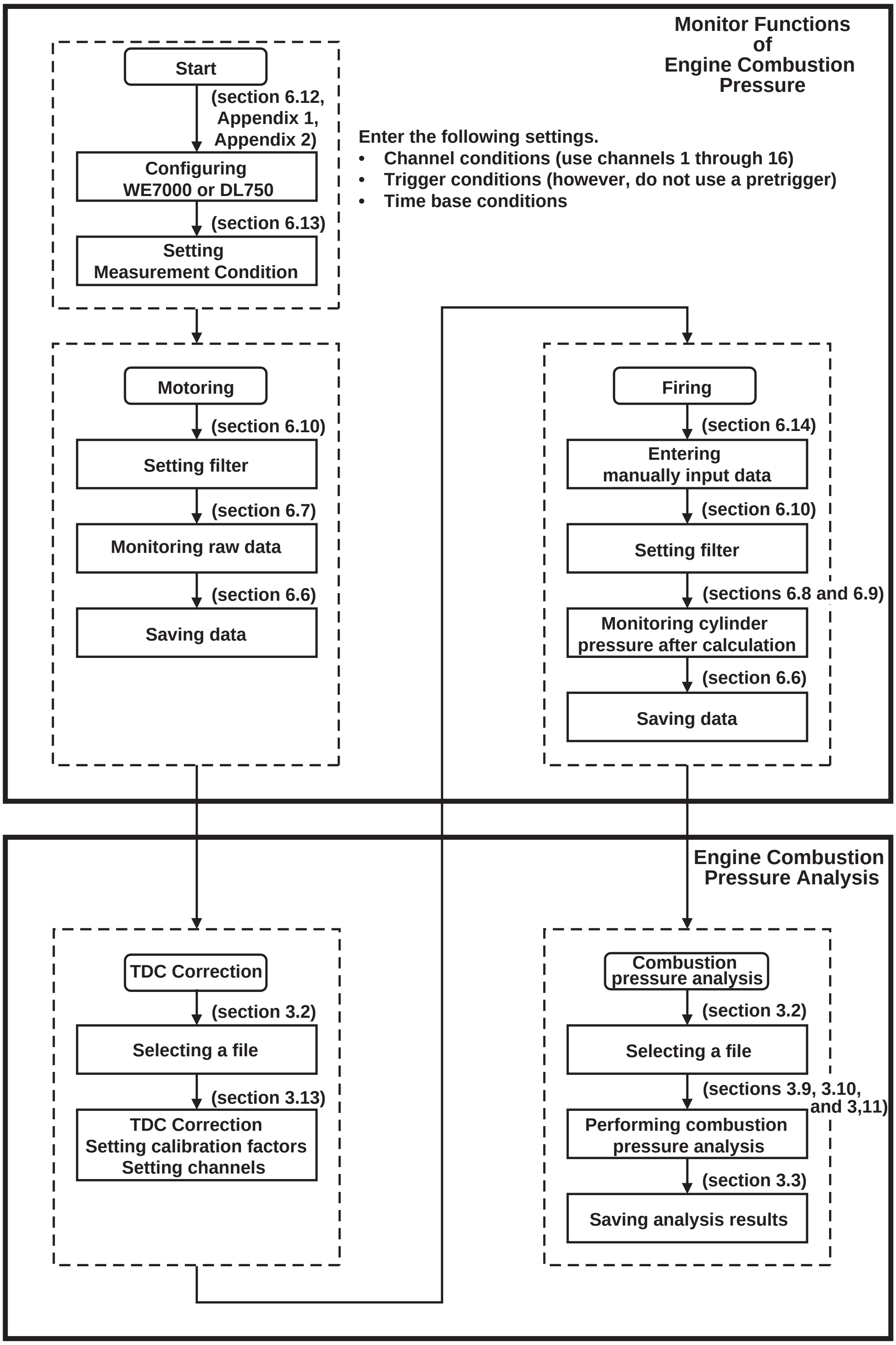
Monitor Items	Crank Angle Graph Monitor	Numerical Value monitor
None	Cylinder pressure P-V graph Other Signals	Maximum cylinder pressure and the corresponding crank angle NMEP IMEP PMEP
dP	Rate of cylinder pressure rise	Maximum rate of cylinder pressure rise and the corresponding crank angle
T	Cylinder gas temperature	Maximum cylinder gas temperature and the corresponding crank angle
dQ	Rate of heat release	Maximum rate of heat release and the corresponding crank angle
Q	Amount of heat release Combustion mass rate	Maximum amount of heat release and the corresponding crank angle Crank angle such that the combustion mass rate is N1 % Crank angle such that the combustion mass rate is N2 % Crank angle such that the combustion mass rate is N3 % Start point of combustion (point a) Etart point of combustion (point b)

  - If filters were applied, the filtered waveforms are displayed.
  - The specified number of cycles of data to undergo combustion pressure analysis is acquired, then saved in WVF format.

- **Entering Conditions**
  Enter the conditions below before executing the monitor function.
  - Measurement conditions
  - Parameter conditions
  - Filter conditions

Procedure

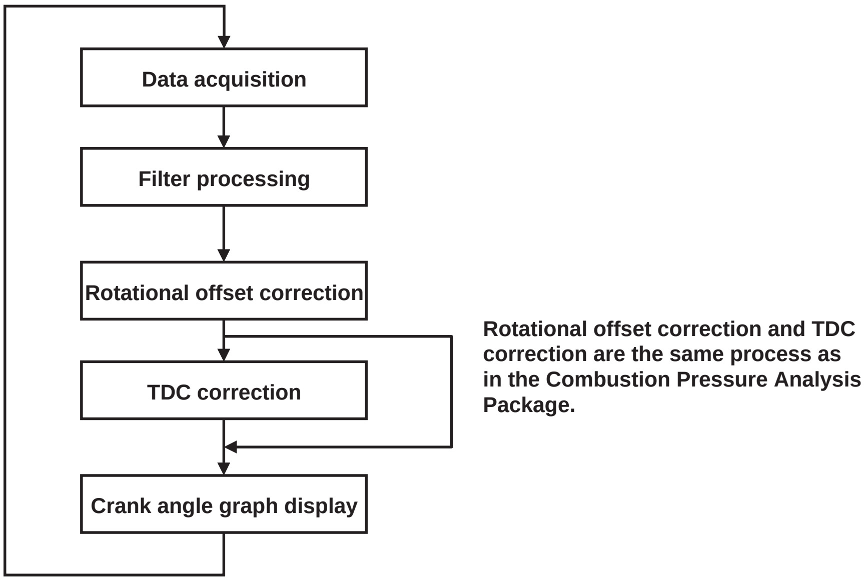
Use the monitor function according to the procedure in the figure below.



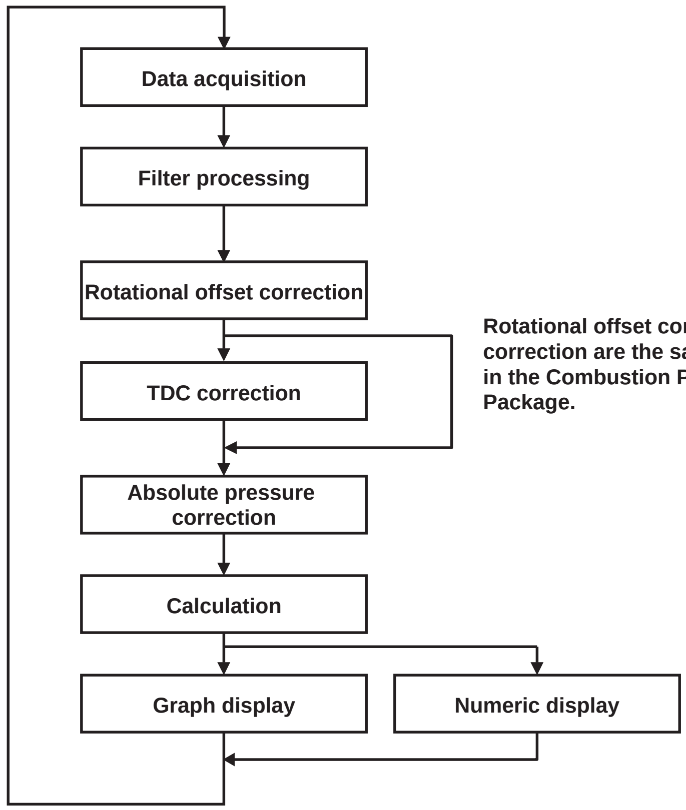
Processing

The monitor function operates as shown in the figure below.

<Motoring Mode>



<Firing Mode>



6.2 Setup

Installing the Software

Use the setup program on the CD to install the Monitor Function.
Run the file, *CD Drive*/Disk1/Setup.exe.
Use the same destination folder for the installation that you used for the Engine Combustion Pressure Analysis.
If your operating system is Windows NT, 2000, or XP, log in as the administrator.

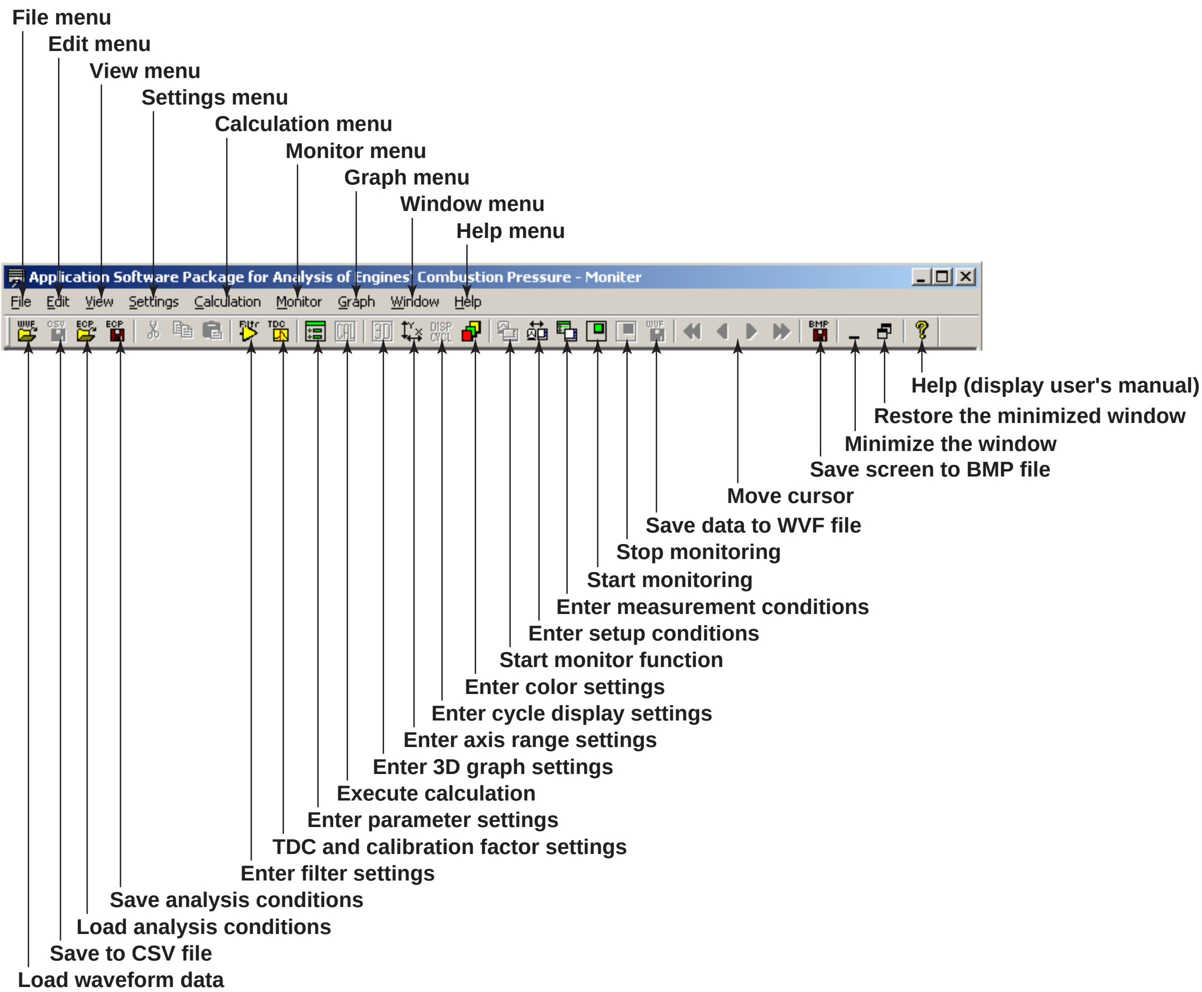
Hardware Configuration

Please see the appendix.

6.3 Screens

Change to this function by choosing File > Start Monitor Functions (see section 3.6). You can also change to this function when the menu bar of the Engine Combustion Pressure Analysis is displayed by selecting (activating) a window related to the monitor function.

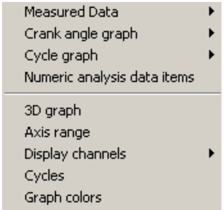
Menu Bar of the Monitor for the Engine Combustion Pressure Analysis Package



6.4 Common Operations

The following operations can be performed when monitoring is interrupted.

Right-Clicking the Mouse



If you right-click on a window displaying a graph, you can execute the following commands from the pull-down menu.

- **Measured Data**: Opens a window displaying a crank angle graph of raw data and corrected data. You can enter these settings while monitoring is being performed.
- **Crank angle graph**: Opens a window displaying a crank angle graph of calculated analysis items. You can enter these settings while monitoring is being performed.
- **Numeric analysis data items**: Opens a window displaying numeric analysis results from calculated analysis items. You can enter these settings while monitoring is being performed.
- **Axis range**: Displays the graph axes setting screen. You can manually enter a fixed value for the X and Y axes, or choose Autoscale.
- **Display channels**: Displays a pull-down menu for display channels.
- **Graph colors**: Displays the graph color setting screen.

Moving the Cursor

Values can be read in directly using the cursor. If you click in a window displaying a graph, the cursor (a vertical bar) jumps to the point where the mouse was clicked, and the X and Y axes of that point are displayed. Cursors (displayed as vertical bars) can be moved from left to right.

: Fast left cursor

: Left cursor

: Right cursor

: Fast right cursor

Displaying the Mouse Pointer Position

When the mouse is moved over a graph, the X and Y value of the current position is displayed on the graph.

Save Screen to BMP File

When monitoring is interrupted, press the button to save a bit map image of the active graph window.

Displaying Help Information

When monitoring is interrupted, you can display the user's manual in PDF format.

6.5 File > Load Measured Data

Functions

- This is the same function as the one described in section 3.2, “File > Load Measured Data.”
- You can select and load previously saved waveform data files. You can analyze previously saved analysis data while monitoring.

6.6 File > Save Monitoring Results

Functions

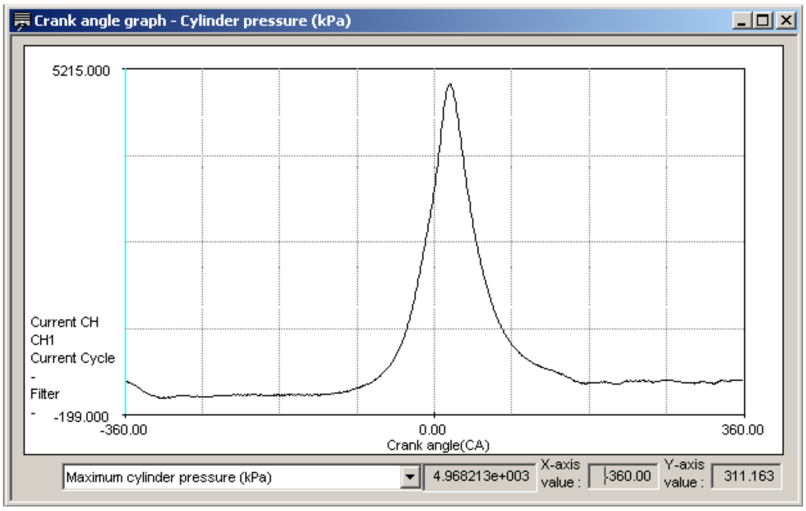
- Automatically pauses monitoring, acquires the specified number of cycles according to the measurement conditions, and displays the File Save dialog box. The saved files contain raw (measured) data that has not undergone TDC correction or filtering.

6.7 View > Measured Data

Functions

- Filters are applied to raw (measured) data according to the filter conditions, which is then displayed in the crank angle graph.
- The following shows the contents of the display for each command.
  View > Measured data > Raw data: Raw (measured) data before TDC correction
  View > Measured data > Corrected data: Raw (measured) data after TDC correction

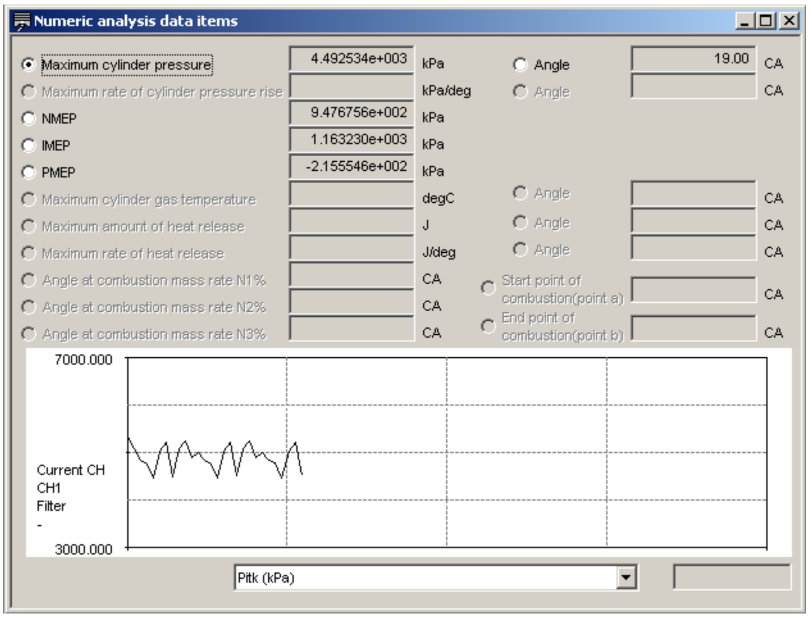
6.8 View > Crank Angle Graph



Functions

- Displays a crank angle graph of the combustion pressure analysis results being monitored.
- The selected values from the numeric analysis data items and the measurement items set to *Use in Calculations* in the Parameter Setting screen are displayed in the lower left portion of the screen.

6.9 View > Numeric Analysis Data Items



Functions

- Displays numeric analysis data items of the combustion pressure analysis results.
- One of the numeric analysis data items is displayed as a trend.
- The selected values from the cycle graph data items and the measurement items set to *Use in Calculations* in the Parameter Setting screen are displayed in the lower right portion of the screen.

6.10 Settings > Filter

Functions

- This is the same function as described in section 3.12, “Settings > Filter.” You can enter these settings when monitoring is paused.
- The settings take effect when monitoring is resumed.

6.11 Settings > TDC Correction and Calibration Factor Settings

Functions

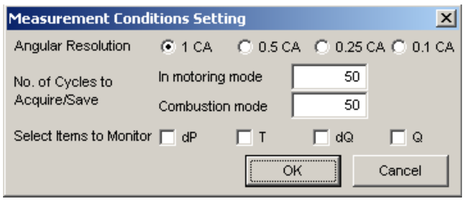
- This is the same function as the one described in section 3.13, “Settings > TDC Correction and Calibration Factor Settings.” There is no execution function for calculation of the TDC correction value. It is manually input.
- The settings take effect when monitoring is resumed.

6.12 Settings > Setup

Functions

- This is the same function as described in section 3.6, “File > Start Monitor Functions.”

6.13 Settings > Measurement Conditions



Functions

- With monitoring stopped, you can enter the angular resolution and number of cycles to be acquired and saved.
- Select the monitor items. The settings take effect when monitoring is resumed.

Monitor Items	Crank Angle Graph Monitor	Numerical Value monitor
None	Cylinder pressure P-V graph Other Signals	Maximum cylinder pressure and the corresponding crank angle NMEP IMEP PMEP
dP	Rate of cylinder pressure rise	Maximum rate of cylinder pressure rise and the corresponding crank angle
T	Cylinder gas temperature	Maximum cylinder gas temperature and the corresponding crank angle
dQ	Rate of heat release	Maximum rate of heat release and the corresponding crank angle
Q	Amount of heat release Combustion mass rate	Maximum amount of heat release and the corresponding crank angle Crank angle such that the combustion mass rate is N1 % Crank angle such that the combustion mass rate is N2 % Crank angle such that the combustion mass rate is N3 % Start point of combustion (point a) Etart point of combustion (point b)

Setting/Display Data

No.	Item	Initial Value	Data Type	Size	Numeric Data Min. Value	Numeric Data Max. Value	Input (I) / Select (S)
1	Angular Resolution	Prev. value	-	-	-	-	S
2	No. of Cycles to Acquire/Save	Prev. value	I	3.0	1	800	I
3	Select Items to Monitor	Prev. value	-	-	-	-	S

(1) **Angular Resolution**: You can select 0.1, 0.25, 0.5, or 1.
(2) **No. of Cycles to Acquire/Save**: Input the number of cycles to acquire.

Button Operations

OK Button

Activates all on-screen settings, and closes the window.

Cancel Button

Clears all on-screen settings, and closes the window.

6.14 Calculation > Set Parameters

Functions

- This is the same function as the one described in section 3.14, "Calculation > Set Parameters."

6.15 Monitor

Functions

- Starts and stops monitoring.

6.16 Graph

Functions

- These are the same functions as the ones described in section 6.4, “Common Operations.”
  They include axis settings, displayed channels, and graph color settings.

7.1 A List of Error Messages

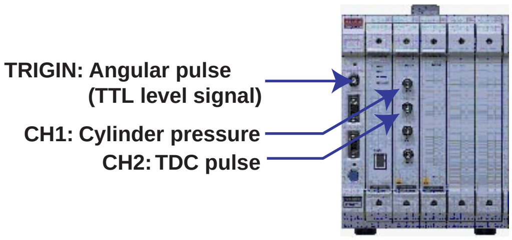
The messages in the table below appear in response to errors that may occur.

Messages	Description
Failed to acquire ASCII header information.	.hdr file not found.
Failed to create analysis work data.	.wvf file does not exist, or WVF file format incorrect.
Setup information is not correct or power to the instrument is not ON.	-
The range defined by the start cycle and end cycle settings exceeds the number of effective cycles. Please reenter the values.	-
Start cycle cannot be greater than the end cycle.	-
Application has already started. (Two simultaneous sessions prohibited.)	-
The default drive may have insufficient free space. Analysis results may not be able to be saved. OK to continue?	-
Analysis results not saved. Save the results?	-
The measuring instrument of the selected waveform data does not match!! If you continue, the data may not be displayed or calculated correctly. Do you still wish to continue?	-
X axis range not entered correctly.	-
Y axis range not entered correctly.	-
Illegal setting value.	The input value exceeded the upper or lower limit for the setting.
Failed to load the analysis conditions.	The format of the analysis file (.ecp) is incorrect.
Cannot exit during monitoring. Please stop monitoring before exiting.	-

Appendix 1 Setting Up the WE7000

First, enter all necessary settings on the WE7000 control software.
The following is an example of how the WE7000 would be configured to measure the pressure in one cylinder assuming one WE7272 module is installed, and a PC is connected.

Sigmal Connection



<Module Settings>

(1) **On**

Connect cylinder pressure signals in the firing order starting from channel 1.
Connect the TDC pulse signal to a channel not being used for cylinder pressure measurement.
In this example, CH1 is assigned to cylinder pressure, and CH2 is assigned to TDC pulse.

(2) **Range**

Set the measurement range appropriate for the input voltage.

(3) **Trig Type**

Uses the TDC pulse signal as the trigger.
Set CH2 to **Rise** or **Fall**.
Turn CH1 (cylinder pressure measurement) **off**.

(4) **Trig Level (V)**

Set the trigger level on the channel connected to TDC pulse (CH2).

(5) **Filter**

Set when the low pass filter is applied as analog processing.

(6) **Acquisition Mode**

Select **Triggered**.

(7) **Memory Partition**

Set to **1**.
This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.

(8) **Record Length**

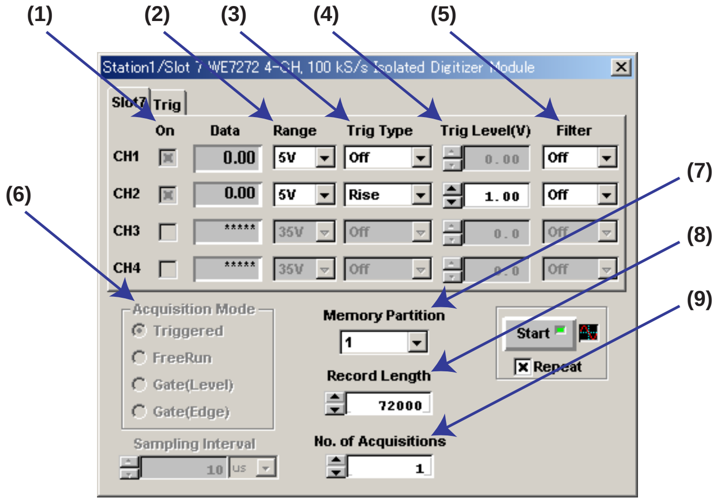
Enter settings as follows:

Record length ≥ (no. of analyzed cycles + 3) × 1 cycle data length
For 4-cycle engine: 1 cycle data length = (360/res) × 2
For 2-cycle engines: 1 cycle data length = (360/res)
res = angular resolution (1, 0.5, 0.25, 0.1)

For example, with a 4-cycle engine at an angular resolution of 0.5 CA, and 100 cycle's worth of data acquired:
From the equation: Record length = (100+3) × 1440 = 148320, enter **148320**.
This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.

(9) **No. of Acquisitions**

Set to **1**.
This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.



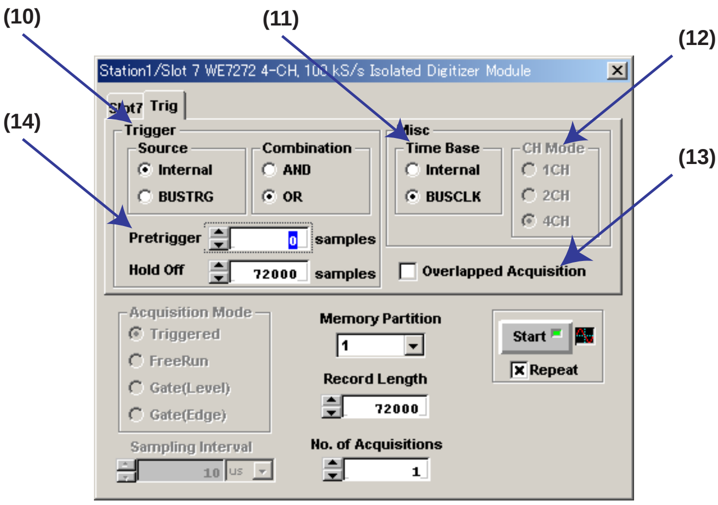
(10) **Trigger/Source**
Select **Internal**.

(11) **Misc/Time Base**
Select **BUSCLK**.

(12) **CH Mode**
Select the number of measurement channels depending on the number of input channels.

(13) **Overlapped Acquisition**
Unselected

(14) **Pretrigger**
Set to **0**.



<Trigger Information Settings>

Enter the following settings for the TDC pulse trigger signal and the angular pulse sampling signal.

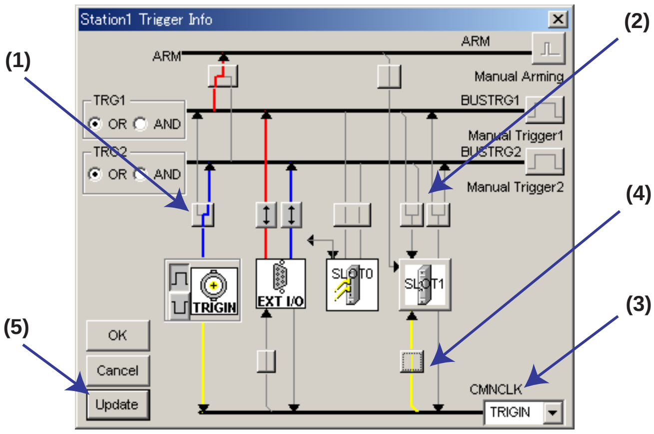
(1) External Trigger Input Switching
Disconnect

(2) Trigger Source Switching
Disconnect

(3) Time base Source
Select **TRIGIN**.

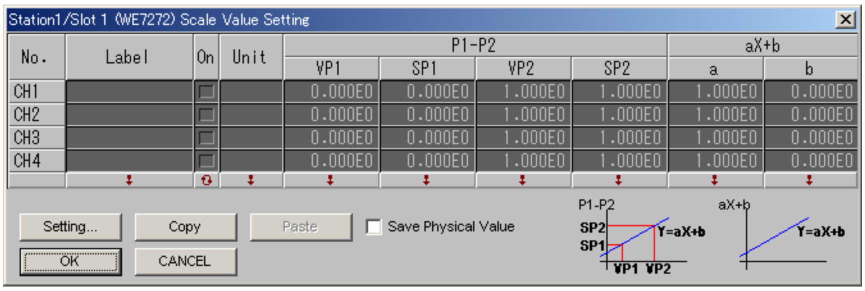
(4) Time base Signal ON/OFF
Connect CMNCLK to the slot as a time base signal.

(5) Press **Update** to apply the settings.



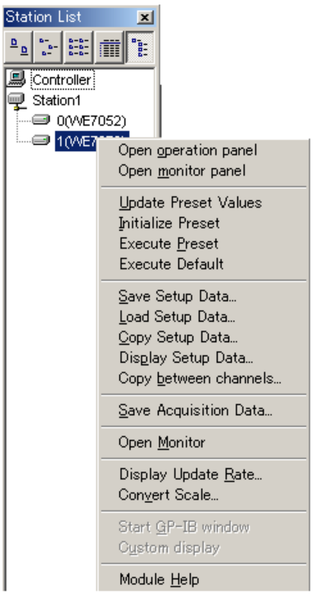
<Scaling Information Settings>

Set all input signal scaling settings to Not Available.



<Sending Settings to the Station>

Right-click the station name for the station list window then select **Update Preset Values** from the menu. The above setting conditions can be sent to the station.



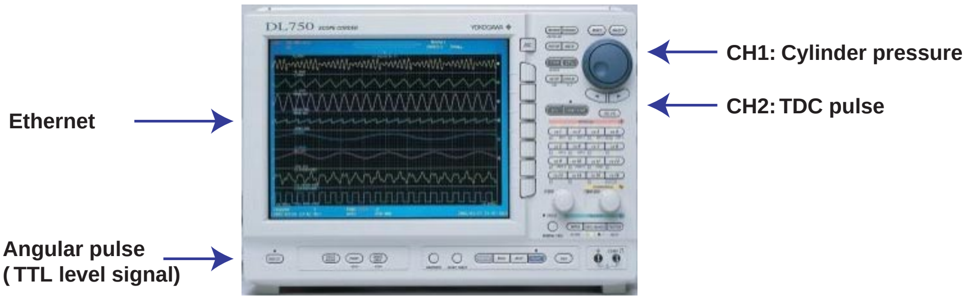
<Exiting the Control software>

Check that you can measure cylinder pressure using the WE7272 and the control software. Exit the control software. This concludes the setup.

Appendix 2 Setting Up the DL750

First, enter all necessary settings on the DL750. The following is an example of how the DL750 would be configured to measure the pressure in one cylinder with one 701251 measurement module.

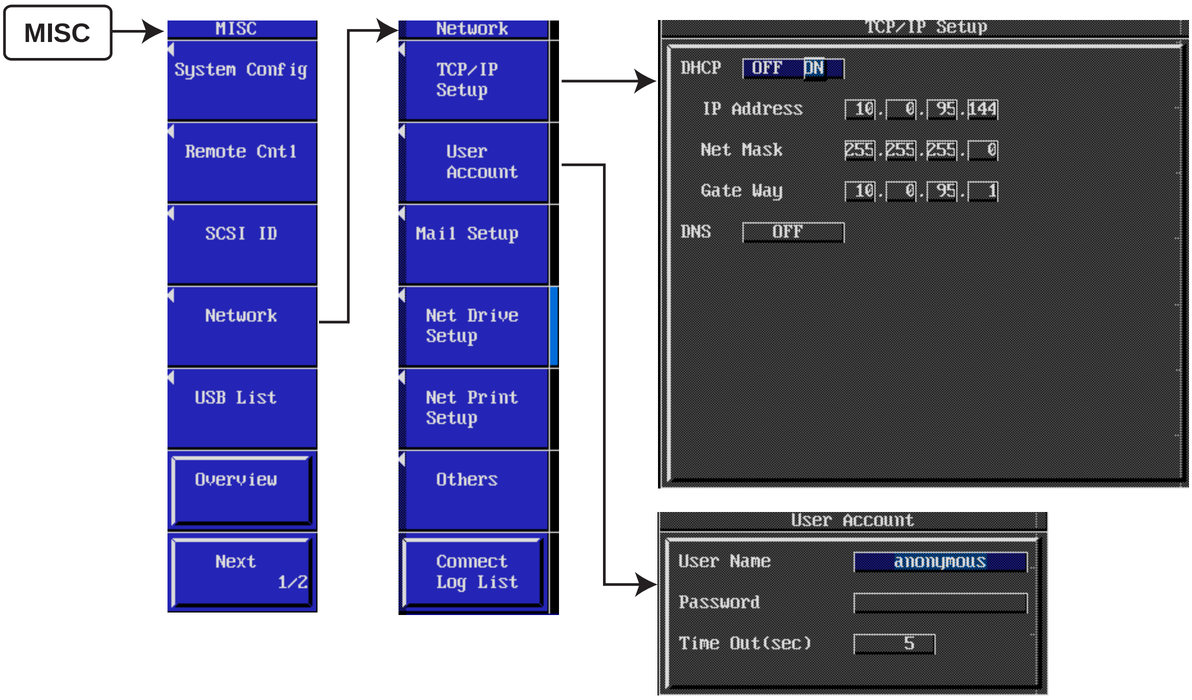
Signal Connection



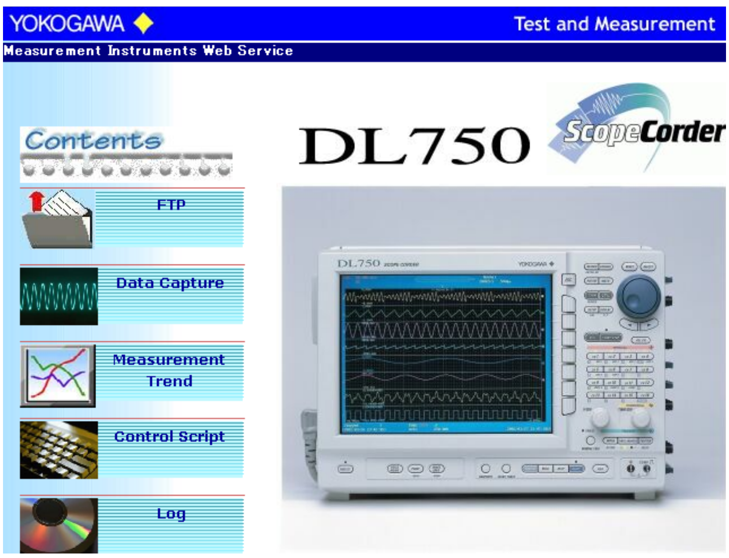
Connect an Ethernet cable to the main unit and turn on the power.

<Network and User Account Settings>

(1) Press the **MISC** key.
(2) Press the **Network** soft key.
(3) Press the **TCP/IP Setup** soft key. The TCP/IP setup menu is displayed.
(4) Press the **User Account** soft key. The User Account Setting menu is displayed.



The setup procedure is explained in the DL750 user's manual. Also, you must enter the network information and user account information that you set here in the Monitor Function add-on for the Engine Combustion Pressure Analysis (see section 6.2).
After entering the above settings, enter the DL750 IP address in a web browser and confirm that the screen below is displayed.



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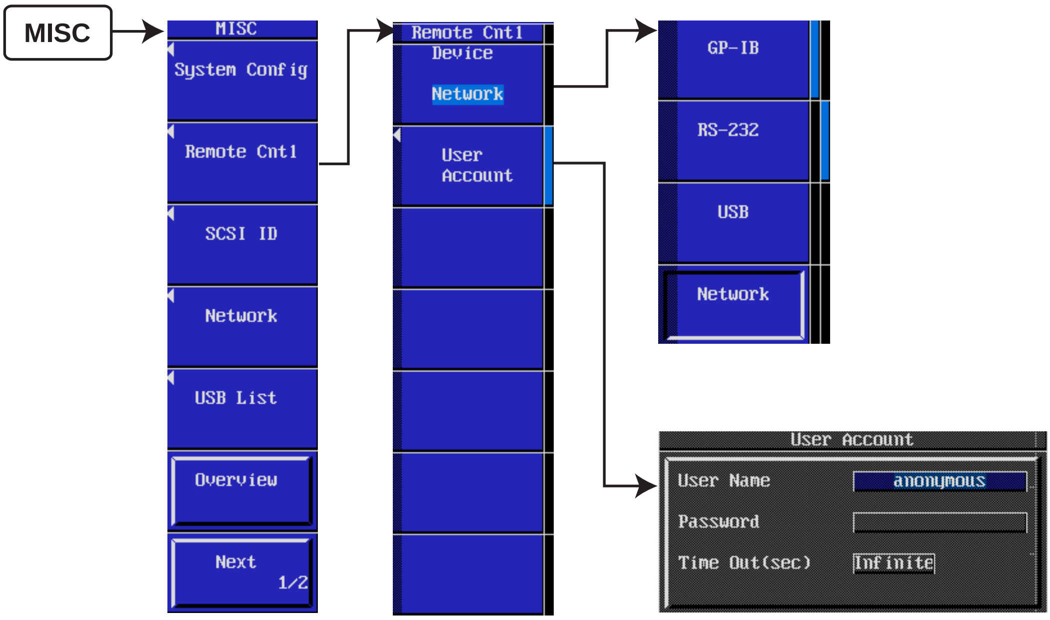
Appendix

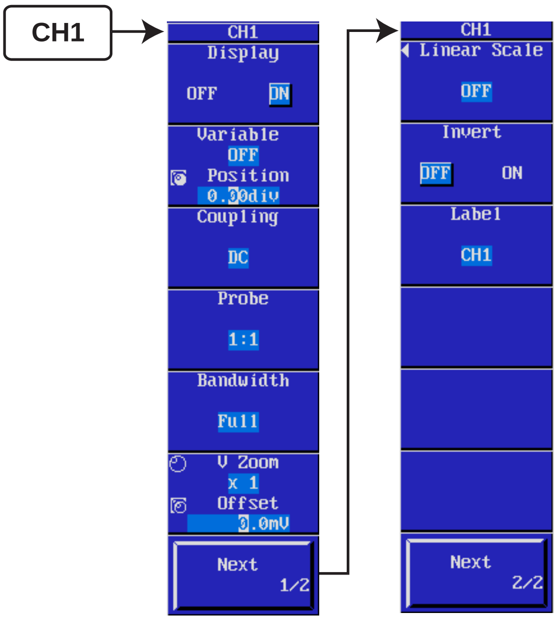
<Remote Control Settings>

Set so that remote control is available through the network.



<CH1 (Cylinder Pressure Signals) Settings>

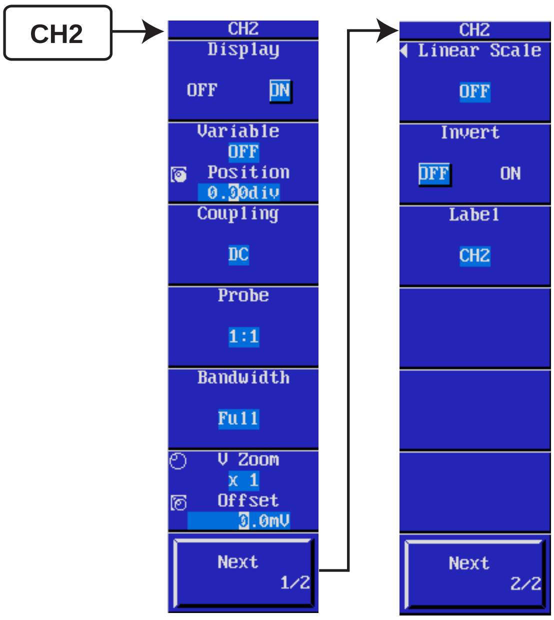
Choose a range using the **V/DIV** knob. Also, press the **CH1** key to enter settings for CH1 as follows:



* Linear Scale = OFF
  Label = CH1

<CH2 (TDC Pulse Signal) Settings>

Choose a range using the **V/DIV** knob. Also, press the **CH2** key to enter settings for CH2 as follows:



* Linear Scale = OFF
  Label = CH2

<Trigger Mode Settings>

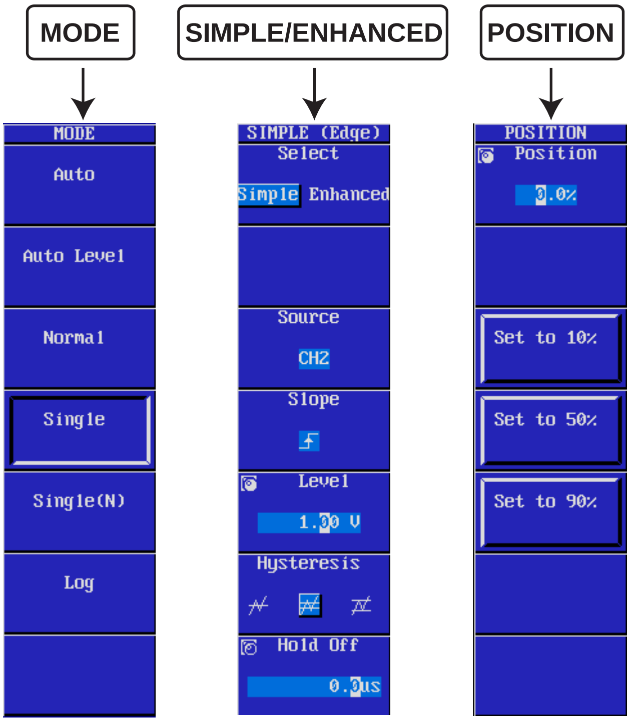
Press the **MODE** key to set the trigger mode to **Single**. This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.

<Trigger Settings>

Press the **SIMPLE/ENHANCED** key, and set the TDC pulse signal (**CH2**) to the trigger source. Enter the Level, Slope, and Hysteresis for the TDC pulse signal.

<Pretrigger Settings>

Press the **POSITION** key to set the Position to **0.0%**.



<Waveform Loading Settings>

Press the **ACQ** key to set the record length and time base.

Enter settings as follows for the record length.

Record length ≥ (no. of analyzed cycles + 3) × 1 cycle data length

For 4-cycle engine: 1 cycle data length = (360/res) × 2

For 2-cycle engines: 1 cycle data length = (360/res)

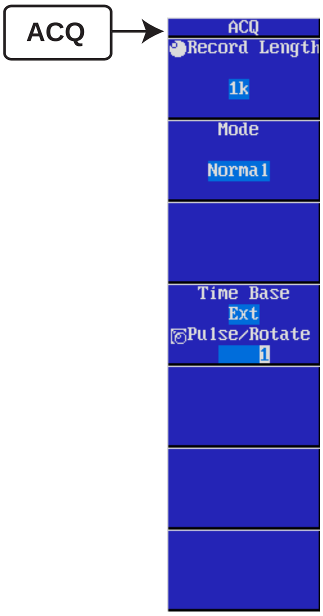
res = angular resolution (1, 0.5, 0.25, 0.1)

For example, with a 4-cycle engine at an angular resolution of 0.5 CA, and 100 cycle's worth of data acquired:

From the equation: Record length = (100+3) × 1440 = 148320, enter **250 k**.

This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.

Set Time Base to **Ext** so that the angular pulse signal will be used as the EXT-CLK.



<Concluding Setup>

Confirm that cylinder pressure can be measured using the START/STOP key. This concludes the setup.

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