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**User's  
Manual**

**Engine Combustion Pressure  
Analysis (707766)  
Monitor Function of Engine  
Combustion Pressure (707769)  
(For Diesel)**

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## 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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## Revisions

1st Edition      March 2004



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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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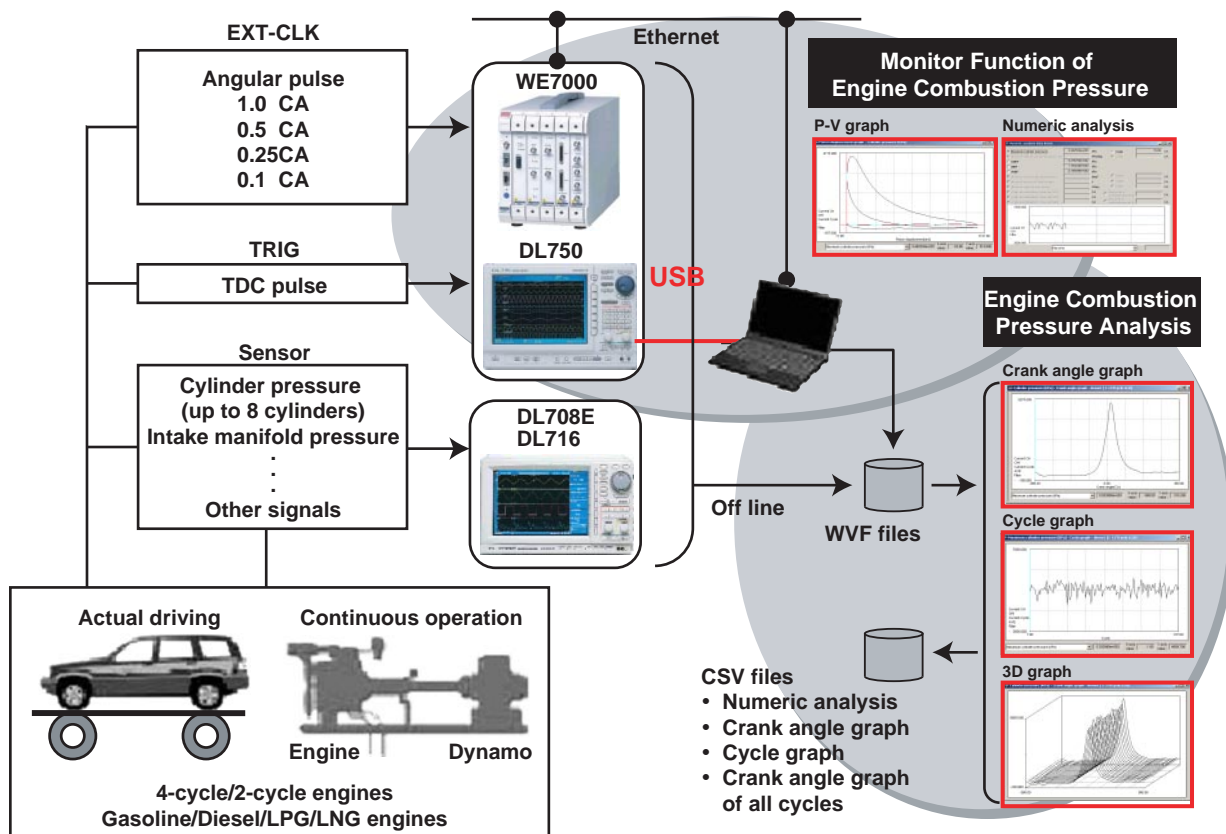
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# 1.1 Hardware Configuration

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 =  $(360/\text{res}) \times 2$
    - For 2-cycle engines: 1 cycle data length =  $(360/\text{res})$
- Measurement module
  - 701852/701853
  - However,  $((\text{RPM}/60) \times 360/\text{res}) < 100 \text{ kHz}$
  - res* : angular resolution (1, 0.5, 0.25, 0.1)



## 1.1 Hardware Configuration

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- **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 =  $(360/\text{res}) \times 2$

For 2-cycle engines: 1 cycle data length =  $(360/\text{res})$

- Measurement module

701251

However,  $((\text{RPM}/60) \times 360/\text{res}) < 1 \text{ MHz}$

*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,  $((\text{RPM}/60) \times 360/\text{res}) < 100 \text{ kHz}$

WE7275

However,  $((\text{RPM}/60) \times 360/\text{res}) < 1 \text{ MHz}$

*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**

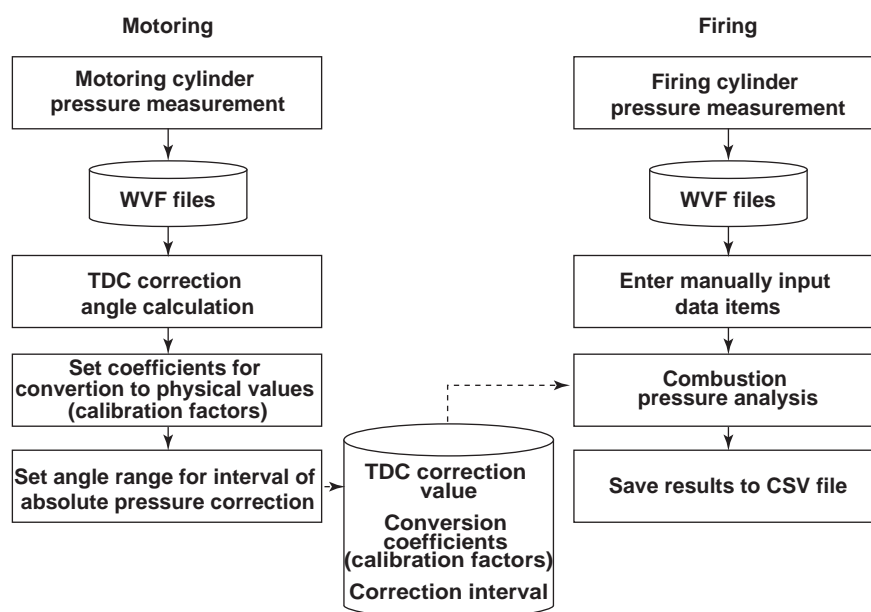
The Monitor Function of Engine Combustion Pressure (hereinafter, the Monitor Function) is an add-on for the Engine Combustion Pressure Analysis.

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  
4<sup>th</sup> 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.

$\% = \text{specified multiple} / (360 \text{ degrees} / \text{angular resolution} (1, 0.5, 0.25, 0.1)) \times 100$

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

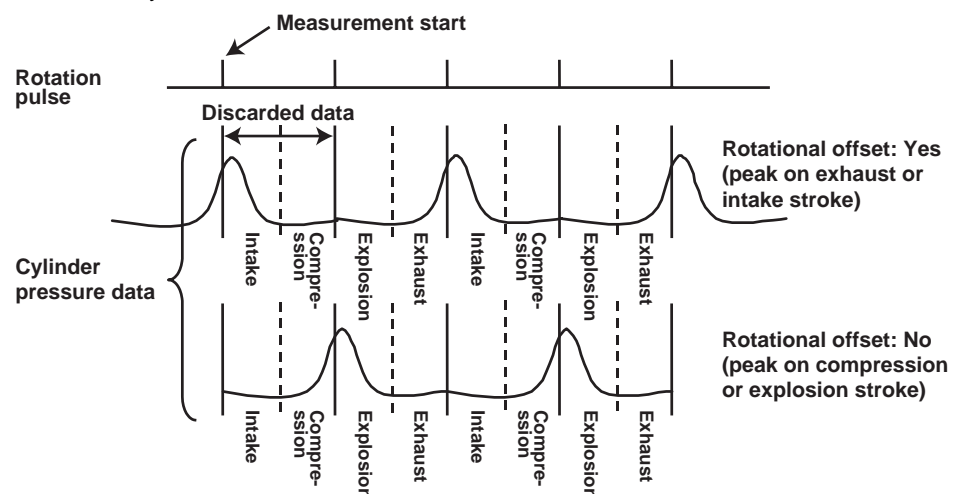
To facilitate checking of measured data, the motoring and firing data are displayed in the crank angle graph.

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.

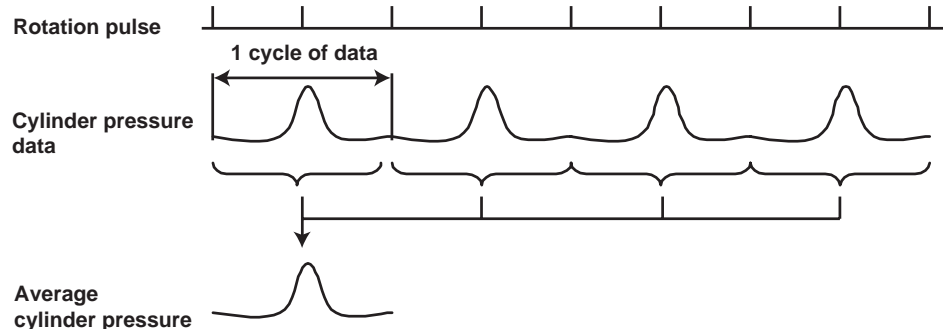


If the crank angle at the maximum point of pressure < -180 CA or if +180 CA < the crank angle at the maximum point of pressure, the rotational offset is set to "yes."

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

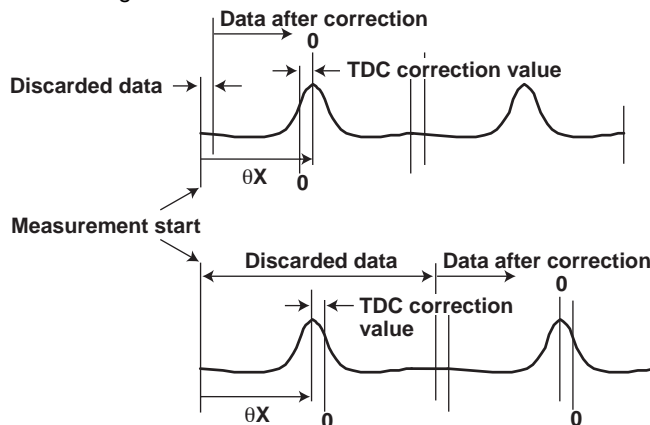
- (1) You can compute the average data for all cycles of the cylinder pressure data from the motoring data of the first cylinder.



- (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  $\theta_X$ .

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

See the figure below.



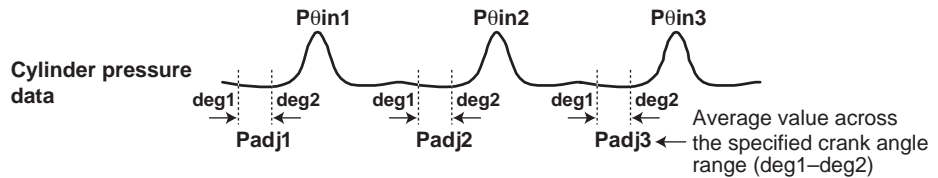
## Absolute Pressure Correction

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

$$\text{Pressure after absolute pressure correction} = P_{\theta in n} - P_{adj n} + P_{x n}$$

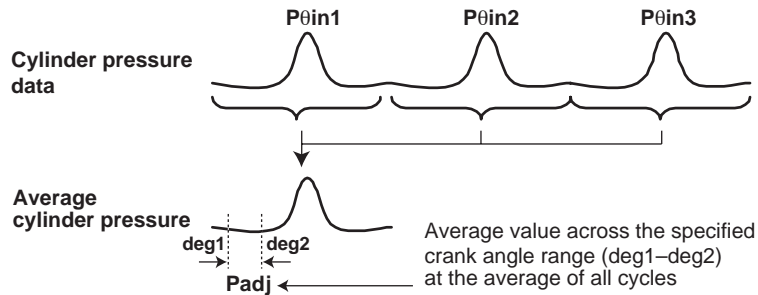
$P_{x n}$ : Atmospheric pressure (including boost pressure) or intake manifold pressure



- When using the all-cycle average value

$$\text{Pressure after absolute pressure correction} = P_{\theta in n} - P_{adj} + P_{x n}$$

$P_{x n}$ : Atmospheric 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
- Rate of heat release (Received heat)
- Rate of heat release (Heat loss)
- Combustion mass rate
- Cylinder gas temperature
- Polytropic index
- Ratio 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
- Rate of heat release (Received heat)
- Rate of heat release (Heat loss)
- Combustion mass rate
- Cylinder gas temperature



## 2.1 Overview of Functions

---

- Polytropic index
- Ratio 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
  - Mass of intake fuel
  - Mass of intake air
  - Excess air factor
  - Corrected gas constant
  - Mass of remaining gas
- **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
- Fuel consumption
- Gas constant
- Atmospheric temperature
- Atmospheric pressure
- Suction volumetric efficiency
- Revolutions per minute
- Specific gravity
- Boost pressure
- Exhaust gas pressure
- Exhaust gas temperature
- Supercharger inlet temperature
- Boost temperature
- Supercharger inlet pressure
- Piston head ratio
- Cylinder wall temperature
- Cylinder head wall temperature
- Piston head wall temperature
- Heat release at lowest position
- Presence/absence of supercharging
- Presence/absence of heat loss processing
- 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, Exhaust Gas Pressure, Exhaust Gas Temperature, Supercharger inlet pressure, Supercharger inlet temperature, and Revolutions per Minute**

### **Saving the Analysis Results of a Specified Range of Cycles**

For the ten 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
- Rate of heat release (received heat)
- Rate of heat release (heat loss)
- Combustion mass rate
- Ratio of specific heat

### **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.

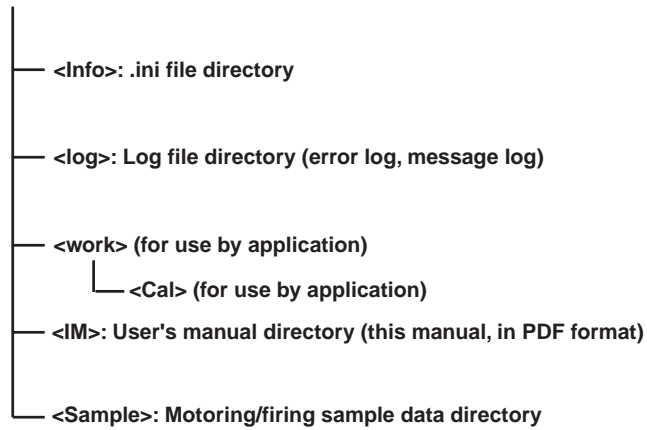
If a previous version of the software is already installed, you must remove it before installing this version.

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## 2.3 Directory Structure

This software utilizes the following directory structure.

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

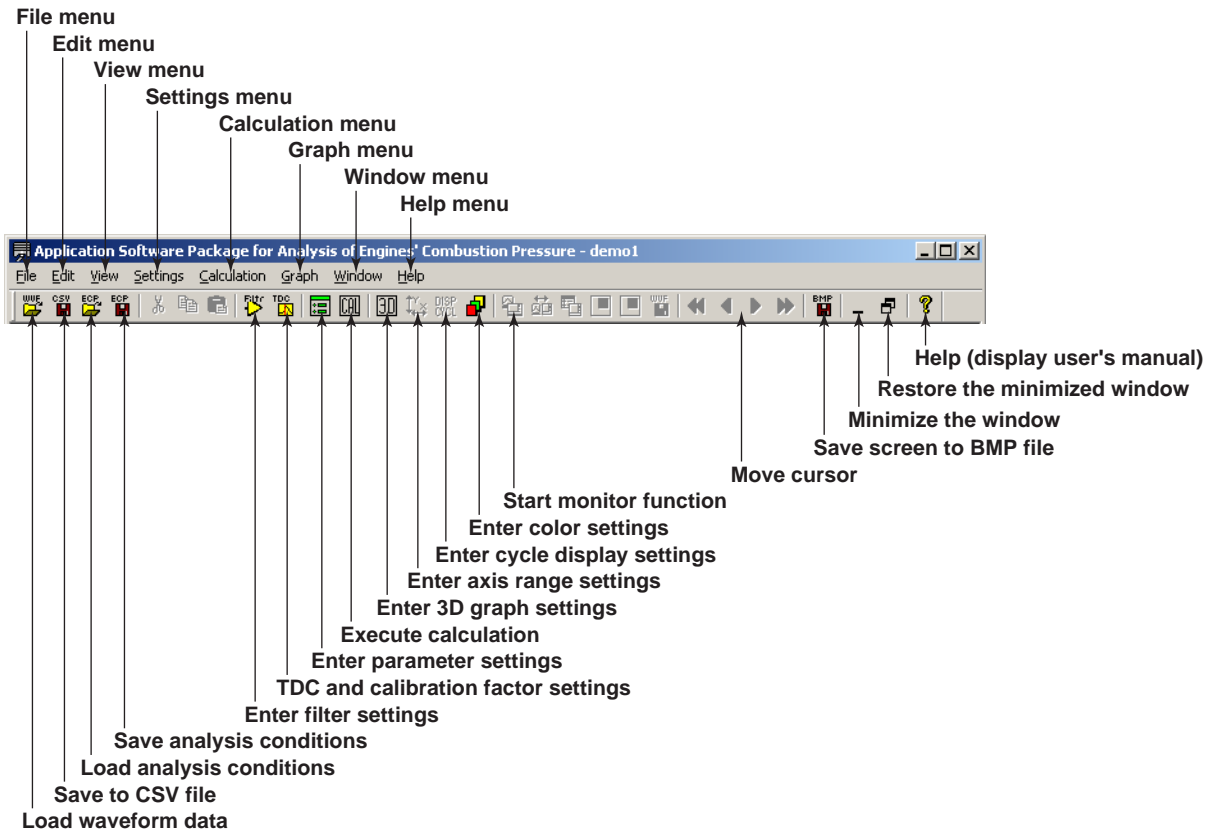


\* If a previous version of the software is already installed, you must remove it before installing this version.

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

## 2.4 Screens

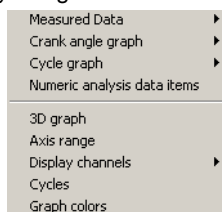
### Menu Bar and Icons for the Engine Combustion Pressure Analysis



## 3.1 Common Operations

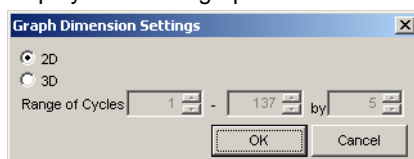
### Right-Clicking the Mouse

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.



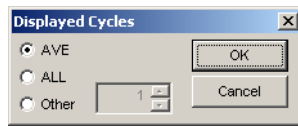
- **Axis range:** Displays the graph axes setting screen. You can set a fixed value for the X and Y axes, or choose Autoscale. These settings are entered for each graph.



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

### 3.1 Common Operations

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

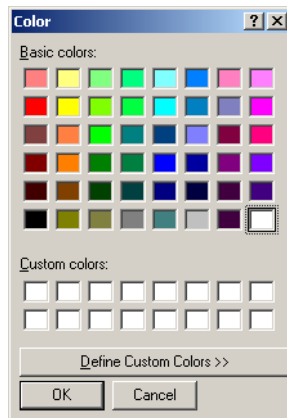
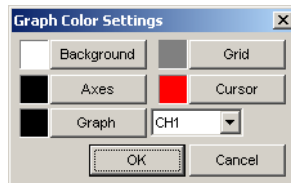


**AVE:** Displays a cycle average crank angle graph

**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

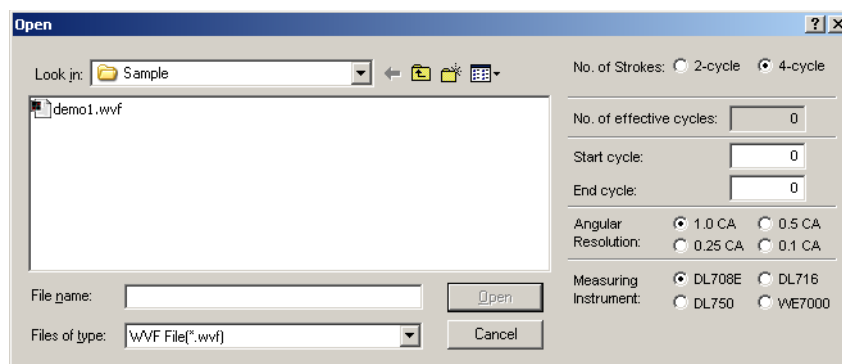
Press the  button to save a bit map image of the active graph window.

#### 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		Input (I) or Select (S)
					Min. Value	Max. Value	
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.

### 3.2 File > Load Measured Data

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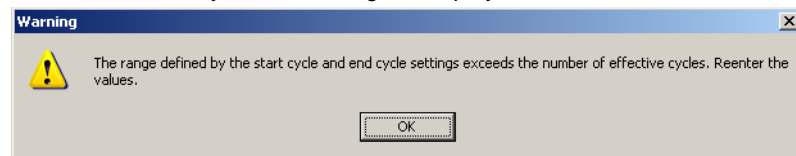
- (4) **Measuring Instrument:** When loading files, the appropriate instrument is automatically selected. You can also change the instrument to the DL708E, DL716, DL750, or WE7000.

#### 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		Input (I) or Select (S)
					Min. Value	Max. Value	
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

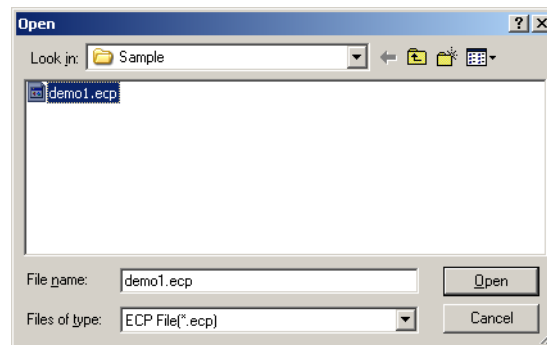
#### Cancel Button

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.

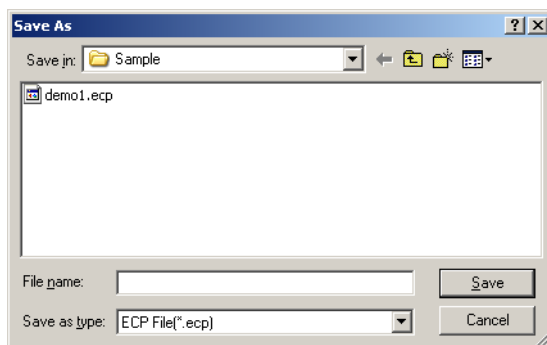
## 3.4 File > Load Analysis Conditions



### 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		Input (I) or Select (S)
					Min. Value	Max. Value	
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.

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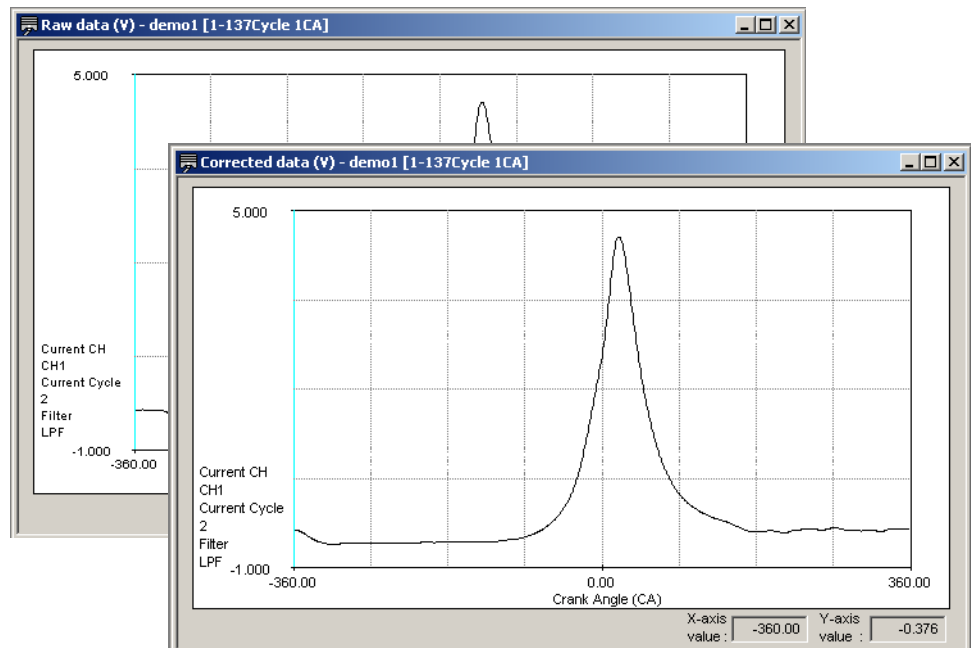
## 3.7 File > Close

### Functions

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



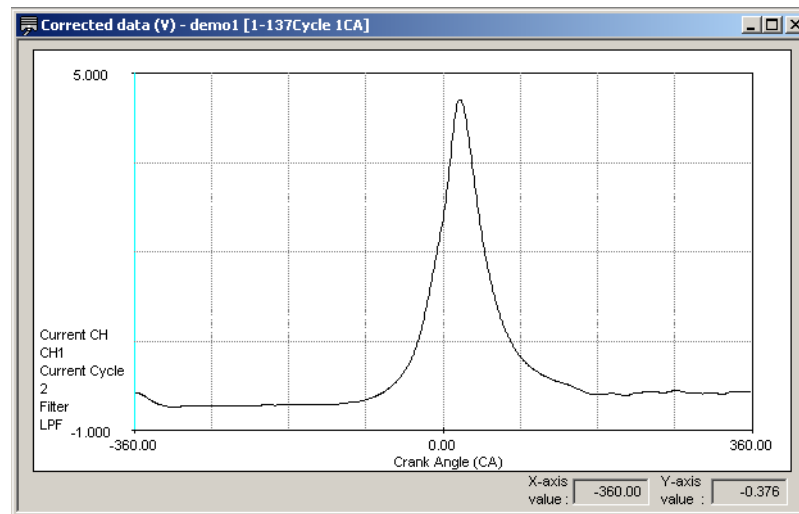
## 3.8 View > Measured Data



### 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



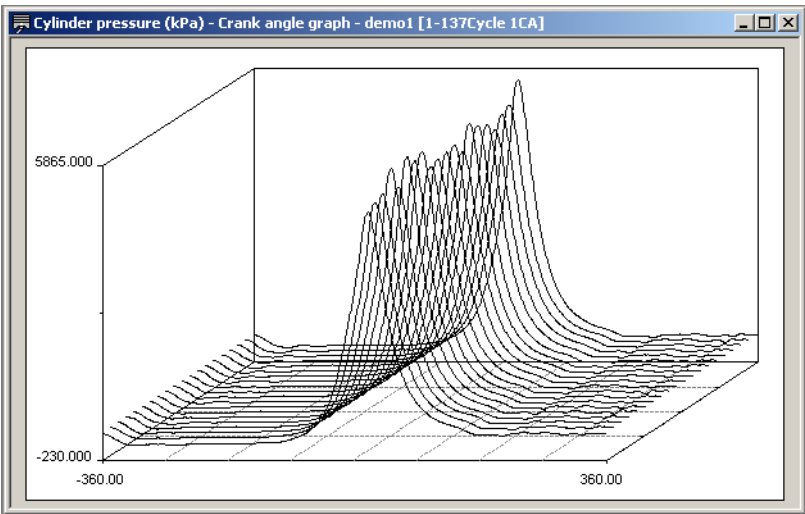
### Functions

- 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.



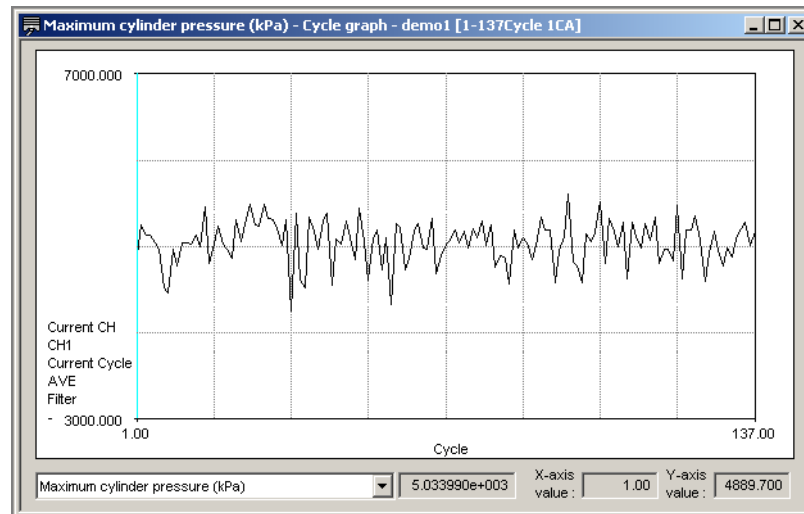
**Functions**

- 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		Input (I) or Select (S)
					Min. Value	Max. Value	
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

Item	Value
Piston displacement (m3)	1.007352e-003
Averaged maximum cylinder pressure...	5.035345e+003
Averaged maximum rate of cylinder pr...	1.276950e+002
Averaged NMEP of all cycles and cylin...	1.022580e+003
Averaged IMEP of all cycles and cylin...	1.237354e+003
Averaged PMEP of all cycles and cylin...	-2.147739e+002
Minimum IMEP of all cycles and cylinde...	1.176703e+003
LNv of IMEP of all cycles and cylinde...	9.509834e+001

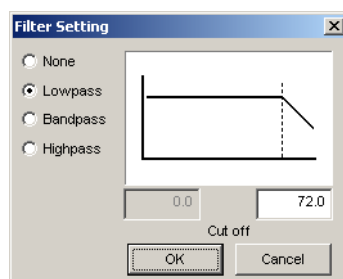
  

Item	P1	P2	P3	P4
Averaged cylinder pressure across c...	-5.875379e+002			
Averaged maximum cylinder pressure...	5.035345e+003			
Standard deviation of maximum cylind...	2.555109e+002			
Rate of change in maximum cylinder p...	5.074347e+000			
Averaged maximum rate of cylinder pr...	1.276950e+002			
Standard deviation of maximum rate of...	2.044104e+001			
Rate of change in maximum rate of cyl...	1.600771e+001			
Averaged NMEP (kPa)	1.022580e+003			
Standard deviation of NMEP (kPa)	1.997706e+001			
Rate of change in NMEP (%)	1.953593e+000			
Averaged IMEP (kPa)	1.237354e+003			

### 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		Input (I) or Select (S)
					Min. Value	Max. Value	
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, rpm, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, supercharger inlet temperature, 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.

### 3.13 Settings > TDC Correction and Calibration Factor Settings

Setting/Display Data

No.	Item	Default Setting	Data Type	Size	Numerical Data		Input (I) or Select (S)
					Min. Value	Max. Value	
1	<i>Calculated TDC Correction Value</i>	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
  - Gfuel: Fuel consumption
  - Ne: Revolutions per minute
  - Td: Intake manifold temperature
  - Pex: Exhaust gas pressure
  - Tex: Exhaust gas temperature
  - Pturb: Supercharger inlet pressure
  - Tturb: Supercharger inlet temperature
  - 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

**Parameter Settings - demo1.wvf**

Con-rod length	180.000 mm	<input checked="" type="radio"/> Fuel consumption	1.0000 cm <sup>3</sup> /s
Bore	110.000 mm	<input type="radio"/> Measured fuel consumption	
Piston offset	0.000 mm	Number of cylinders	1
Stroke	106.000 mm	Low heat value	49372000 J/kg
Piston head ratio	1.000	Gas constant	29.270
<input checked="" type="radio"/> Clearance volume	62.960 cm <sup>3</sup>	Suction volumetric efficiency	80.000 %
<input type="radio"/> Compression ratio	17.000	Specific gravity	0.800 g/cm <sup>3</sup>
<input type="radio"/> Without supercharging		Cylinder head wall temperature	200.000 degC
<input type="radio"/> With supercharging		Cylinder wall temperature	200.000 degC
Boost pressure	0.000 kPa	Piston head wall temperature	200.000 degC
<input checked="" type="radio"/> Supercharger inlet pressure	102.000 kPa	<input checked="" type="radio"/> Exhaust gas pressure	102.000 kPa
<input type="radio"/> Measured supercharger inlet pressure		<input type="radio"/> Measured exhaust gas pressure	
<input checked="" type="radio"/> Supercharger inlet temperature	30.000 degC	<input checked="" type="radio"/> Exhaust gas temperature	550.000 degC
<input type="radio"/> Measured supercharger inlet temperature		<input type="radio"/> Measured exhaust gas temperature	
Boost temperature	30.000 degC	<input checked="" type="radio"/> Revolutions per minute	1200 rpm
<input type="radio"/> Presence of heat loss processing		<input type="radio"/> Measured revolutions per minute	
<input checked="" type="radio"/> Absence of heat loss processing		<input checked="" type="radio"/> Atmospheric temperature	25.000 degC
<input type="radio"/> Start point of combustion	0.00 CA	<input type="radio"/> Measured intake manifold temperature	
<input checked="" type="radio"/> Number of data items for judging start point of combustion	5	<input checked="" type="radio"/> Atmospheric pressure	102.404 kPa
<input type="radio"/> End point of combustion	0.00 CA	<input type="radio"/> Measured intake manifold pressure	
<input checked="" type="radio"/> Number of data items for judging end point of combustion	5	<input type="radio"/> Absolute pressure correction for each cycle	
Window for searching maximum rate of heat release	-360.00 - 359.00 CA	<input checked="" type="radio"/> Absolute pressure correction for cycle average	
Ratio for judging angle of combustion mass rate N1	50 %		
Ratio for judging angle of combustion mass rate N2	50 %		
Ratio for judging angle of combustion mass rate N3	50 %		
Value for judging misfire	100.000 kPa		

OK Cancel

### 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, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, and supercharger inlet temperature.
- 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		Input (I) or Select (S)
						Min. Value	Max. Value	
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	Piston head ratio	-	Prev. value	F	9.3	0.000	99999.999	I
6	Clearance volume	cm <sup>3</sup>	Prev. value	F	9.3	0.000	99999.999	I or S
7	Compression ratio	-	Prev. value	F	6.3	0.000	99.999	I or S
8	With/Without supercharging	-	Prev. value	-	-	-	-	S
9	Boost pressure	kPa	Prev. value	F	9.3	0.000	99999.999	I or S
10	Supercharger inlet pressure	kPa	Prev. value	F	9.3	0.000	99999.999	I or S
11	Measured supercharger inlet pressure	-	-	-	-	-	-	S
12	Supercharger inlet temperature	°C	Prev. value	F	9.3	-273.000	99999.999	I or S
13	Measured supercharger inlet temperature	-	-	-	-	-	-	S
14	Boost temperature	°C	Prev. value	F	9.3	-273.000	99999.999	I or S
15	Presence/absence of heat loss processing	-	-	-	-	-	-	S
16	Start point of combustion	CA	Prev. value	F	6.2	-360.00	359.99	I
17	Number of data items for judging start point of combustion	-	Prev. value	I	2.0	3	99	I
18	End point of combustion	CA	Prev. value	F	6.2	-360.00	359.99	I
19	Number of data items for judging end point of combustion	-	Prev. value	I	2.0	3	99	I
20	Window of searching maximum rate of heat release	CA	Prev. value	F	6.2	-360.00	359.99	I
21	Ratio for judging angle of combustion mass rate	%	Prev. value	I	2.0	5	95	I
22	Value for judging misfire	kPa	Prev. value	F	9.3	0.000	99999.999	I
23	Fuel consumption	cm <sup>3</sup> /s	Prev. value	F	9.3	0.000	99999.999	I or S
24	Measured fuel consumption	-	-	-	-	-	-	S
25	Number of cylinders	-	Prev. value	I	1.0	1	8	I or S
26	Low heat value	J/kg	Prev. value	I	9	0	999999999	I
27	Gas constant (x9.80665 J/kg.K)	-	Prev. value	F	9.3	0.000	99999.999	I
28	Suction volumetric efficiency %		Prev. value	F	9.3	0.000	99999.999	I
29	Specific gravity	-	Prev. value	F	9.3	0.000	99999.999	I
30	Cylinder head wall temperature	°C	Prev. value	F	9.3	0.000	99999.999	I
31	Cylinder wall temperature	°C	Prev. value	F	9.3	0.000	99999.999	I
32	Piston head wall temperature	°C	Prev. value	F	9.3	0.000	99999.999	I
33	Exhaust gas pressure	kPa	Prev. value	F	9.3	0.000	99999.999	I
34	Measured exhaust gas pressure	-	-	-	-	-	-	S
35	Exhaust gas temperature	°C	Prev. value	F	9.3	0.000	99999.999	I

### 3.14 Calculation > Set Parameters

No.	Item	Unit	Default Setting	Data Type	Size	Numerical Data		Input (I) or Select (S)
						Min. Value	Max. Value	
36	Measured exhaust gas temperature	-	-	-	-	-	-	S
37	Revolutions per minute	rpm	Prev. value	I	5.0	0	99999	I or S
38	Measured revolutions per minute	-	-	-	-	-	-	S
39	Atmospheric temperature	°C	Prev. value	F	9.3	-273.000	99999.999	I or S
40	Measured intake manifold temperature	-	-	-	-	-	-	S
41	Atmospheric pressure	kPa	Prev. value	F	9.3	0.000	99999.999	I or S
42	Measured intake manifold pressure	-	-	-	-	-	-	S
43	<i>Method of absolute pressure correction</i>	-	-	-	-	-	-	S

- (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 fuel consumption and Number of cylinders:** Measures the fuel consumption, and when using the result for calculations, you can select this item or specify how many cylinders worth of fuel consumption it represents. In the TDC Correction and Calibration Factor Setting screen, it is assumed that fuel consumption (Gfuel) is assigned to a channel.
- (5) **Measured exhaust gas pressure:** Select this item when measuring the pressure of exhaust gas and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that exhaust gas pressure (Pex) is assigned to a channel.
- (6) **Measured exhaust gas temperature:** Select this item when measuring the temperature of exhaust gas and using the result for calculations. In the TDC Correction and Calibration Factor Setting screen, it is assumed that exhaust gas temperature (Tex) is assigned to a channel.
- (9) **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.
- (10) **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.
- (11) **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.

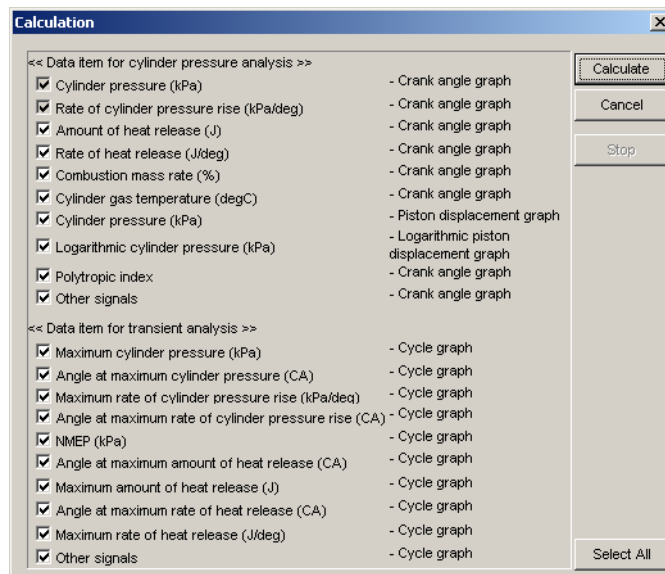
**Button Operations****OK** Button

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)
  - Piston head ratio
  - Clearance volume (m<sup>3</sup>)
  - Compression ratio
  - Presence/absence of supercharging
  - Supercharger inlet pressure (kPa)
  - Supercharger inlet temperature (°C)
  - Boost temperature (°C)
  - Presence/absence of heat loss processing
  - 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)
  - Fuel consumption (m<sup>3</sup>/s)
  - Number of cylinders (used to calculate fuel consumption)
  - Heat release at lowest position (J/kg)
  - Gas constant (×9.80665 J/kg.K)

Suction volumetric efficiency (%)  
Specific gravity  
Cylinder head wall temperature (°C)  
Cylinder wall temperature (°C)  
Piston head wall temperature (°C)  
Exhaust gas pressure (kPa)  
Exhaust gas temperature (°C)  
Revolutions per minute (rpm)  
Atmospheric temperature (°C)  
Atmospheric pressure (kPa)  
Method of absolute pressure correction

### 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<sup>3</sup>)
  - 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 (%)  
 Mass of intake fuel (kg)  
 Mass of intake air (kg)  
 Excess air factor  
 Corrected gas constant  
 Mass of remaining gas (kg)

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

Crank angle  
 Average cylinder pressure (kPa)  
 Logarithmic average cylinder pressure (kPa)  
 Piston displacement (m)  
 Piston displacement (m<sup>3</sup>)  
 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 (%)  
 Ratio of specific heat  
 Polytropic index  
 Rate of heat release (Received heat) (J/deg)  
 Rate of heat release (Heat loss) (J/deg)

- **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)

## 4.1 Saved Items

---

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 (cm<sup>3</sup>/s)  
Revolutions per minute (rpm)  
Intake manifold temperature (°C)  
Exhaust gas pressure (kPa)  
Exhaust gas temperature (°C)  
Supercharger inlet pressure (kPa)  
Supercharger inlet temperature (°C)  
Other signals (Crank angle graph data)

- **Calculation Data Items: Cycle Graph Data Items (Other Signals)**

Cycle  
Intake manifold pressure (kPa)  
Fuel consumption (cm<sup>3</sup>/s)  
Revolutions per minute (rpm)  
Intake manifold temperature (°C)  
Exhaust gas pressure (kPa)  
Exhaust gas temperature (°C)  
Supercharger inlet pressure (kPa)  
Supercharger inlet temperature (°C)  
Other signals (Cycle 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  
Rate of heat release (Received heat) (J/deg)  
Rate of heat release (Heat loss) (J/deg)  
Intake manifold pressure (kPa)  
Fuel consumption (cm<sup>3</sup>/s)  
Revolutions per minute (rpm)  
Intake manifold temperature (°C)  
Exhaust gas pressure (kPa)  
Exhaust gas temperature (°C)  
Supercharger inlet pressure (kPa)  
Supercharger inlet temperature (°C)  
Other signals (Crank angle graph data)

\* Intake manifold pressure, fuel consumption, rpm, intake manifold temperature, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, and supercharger inlet temperature 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. P $\theta$ in

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

$$P\theta \text{ in} = A \times U[720, N] + B$$

- 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

$$Padj[N] = \text{ave}(P\theta \text{ in}[\theta = \text{adj } \theta 1 \text{ to adj } \theta 2, N]) \quad \# \text{ ave: average value}$$

For all-cycle average

$$Padj[N] = \text{ave}(P\theta \text{ in\_ave}[\theta = \text{adj } \theta 1 \text{ to adj } \theta 2]) \quad \# \text{ ave: average value}$$

- N: Number of cycles  
 P $\theta$  in: Cylinder pressure (kPa) (calculated value) of the specified range of cycles extracted after rotational offset correction and TDC correction  
 P $\theta$  in\_ave: Average cylinder pressure (kPa) (calculated value)  
 $P\theta \text{ in\_ave}[720] = (1 / N) \times \Sigma(P\theta \text{ in}[720, N])$   
 adj  $\theta$  1: Starting angle (CA) of the range used for absolute pressure correction (manually input)  
 adj  $\theta$  2: 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:

$$Pitk\_ave[N] = \text{ave}(P\theta \text{ itk}[720, N]) \quad \# \text{ ave: average value}$$

- N: Number of cycles  
 P $\theta$  itk: Intake manifold pressure (kPa) (measured value)

### 4. P $\theta$ [720, N]

Cylinder pressure after absolute pressure correction (kPa)

- When the atmospheric and boost pressures are manually input,  
 $P\theta [720, N] = P\theta \text{ in}[720, N] - Padj[N] + Pa + Pt$
- When depending on the measured intake manifold pressure,  
 $P\theta [720, N] = P\theta \text{ in}[720, N] - Padj[N] + Pitk\_ave [N]$

- N: Number of cycles  
 P $\theta$  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. logP $\theta$ [720, N]

Logarithmic cylinder pressure (kPa)

$$\log P_{\theta} [720, N] = \log_{10}(P_{\theta} [720, N])$$

N: Number of cycles

P $\theta$  : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

### 6. P $\theta$ ave[720]

Average cylinder pressure (kPa)

$$P_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(P_{\theta}[720, N])$$

N: Number of cycles

P $\theta$ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

### 7. logP $\theta$ ave[720]

Logarithmic average cylinder pressure (kPa)

$$\log P_{\theta} \text{ ave}[720] = \log_{10}(P_{\theta} \text{ ave}[720])$$

P $\theta$  ave: Average cylinder pressure (kPa) (calculated value)

### 8. X $\theta$ [720]

Piston displacement (m)

$$R = S / 2$$

$$\phi = \arcsin(\gamma / (L + R))$$

$$X_{\theta} [720] = \sqrt{((R+L)^2 - \gamma^2) - R \times \cos((\theta + \alpha) \times (\pi / 180) + \phi)} - \sqrt{L^2 - (-R \times \sin((\theta + \alpha) \times (\pi / 180) + \phi) + \gamma)^2} \quad \# \text{ sqrt: square root}$$

S: Stroke length (m) (manually input)

L: Con-rod length (m) (manually input)

$\gamma$ : Piston offset (m) (manually input)

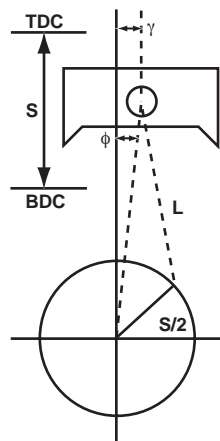
$\theta$ : Crank angle (CA) radian

4-cycle engine: -360 to +359 CA: at 1 CA resolution

2-cycle engine: -180 to +179 CA: at 1 CA resolution

$\alpha$ : 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  $(\theta + \alpha) = 0 + \alpha, 1 + \alpha, \dots$

$\pi$ : The circular constant



9.  $V_{\theta}$  [720]

Piston displacement ( $m^3$ )

When **Clearance volume** is selected on the Parameter Settings screen

$$V_{\theta} [720] = (\pi / 4) \times B^2 \times X_{\theta} [720] + V_c$$

When **Compression ratio** is selected on the Parameter Settings screen

$$V_{\theta} [720] = (\pi / 4) \times B^2 \times X_{\theta} [720] + V_{st} / (Cr - 1)$$

$\pi$ :	The circular constant
B:	Bore (m) (manually input)
$X_{\theta}$ :	Piston displacement (m) (calculated value)
$V_c$ :	Clearance volume ( $m^3$ ) (manually input)
$V_{st}$ :	Piston displacement ( $m^3$ ) (calculated value)
Cr:	Compression ratio (manually input)

10.  $dV_{\theta}$  [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  $(V_{\theta 001}, V_{\theta 002})$

$V_{\theta}$ :	Piston displacement ( $m^3$ ) (calculated value)
res:	Angular resolution (1, 0.5, 0.25, or 0.1 CA)

11.  $\log V_{\theta}$  [720]

Logarithmic piston displacement ( $m^3$ )

$$\log V_{\theta} [720] = \log_{10}(V_{\theta} [720])$$

$V_{\theta}$ :	Piston displacement ( $m^3$ ) (calculated value)
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12.  $dP_{\theta}$  [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
$P_{\theta}$ :	Cylinder pressure (kPa) after absolute pressure correction (calculated value)
res:	Angular resolution (1, 0.5, 0.25, or 0.1 CA)

13.  $dP_{\theta} \text{ ave}$  [720]

Average rate of cylinder pressure rise (kPa/deg)

$$dP_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(dP_{\theta} \text{ in}[720,N])$$

N :	Number of cycles
$dP_{\theta}$ :	Rate of cylinder pressure rise (kPa/deg) (calculated value)

### 14. Pmax[N]

Maximum cylinder pressure (kPa)

$$P_{\max}[N] = \max(P_{\theta} [720, N]) \quad \# \text{ max: maximum value}$$

N : Number of cycles

P<sub>θ</sub> : Cylinder pressure (kPa) (calculated value)

### 15. θPmax [N]

Crank angle at maximum cylinder pressure (CA)

$$\theta P_{\max}[N] = \text{pos}(P_{\theta} [720, N]) \quad \# \text{ pos: crank angle at max. cylinder pressure}$$

N : Number of cycles

P<sub>θ</sub> : Cylinder pressure (kPa) (calculated value)

### 16. θPmax\_ave

Averaged crank angle at maximum cylinder pressure (CA)

$$\theta P_{\max\_ave} = (1 / N) \times \Sigma(\theta P_{\max} [N])$$

N : Number of cycles

θPmax : Crank angle at maximum cylinder pressure (CA) (calculated value)

### 17. Pmax\_ave

Averaged maximum cylinder pressure (kPa)

$$P_{\max\_ave} = (1 / N) \times \Sigma(P_{\max} [N])$$

N : Number of cycles

Pmax : Maximum cylinder pressure (kPa) (calculated value)

### 18. Pmax\_std

Standard deviation of maximum cylinder pressure (kPa)

$$P_{\max\_std} = \sqrt{(1 / (N-1)) \times \Sigma(P_{\max} [N] - P_{\max\_ave})^2} \quad \# \text{ sqrt: square root}$$

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

$$P_{\max\_cov} = (P_{\max\_std} / P_{\max\_ave}) \times 100$$

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)

$$P_{\max\_cy}[N] = (1 / Cy) \times \Sigma(P_{\max} [Cy, N])$$

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)

$$P_{\max\_Cy\_ave} = (1 / N) \times \Sigma(P_{\max\_Cy} [N])$$

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)

$$\theta P_{\max\_Cy}[N] = (1 / Cy) \times \Sigma(\theta P_{\max} [Cy, N])$$

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)

$$\theta P_{\max\_Cy\_ave} = (1 / N) \times \Sigma(\theta P_{\max\_Cy} [N])$$

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)

$$dP_{\max}[N] = \max(dP_{\theta} [720, N]) \quad \# \text{ max: maximum value}$$

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)

$$\theta dP_{\max}[N] = \text{pos}(dP_{\theta} [720, N])$$

# 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)

$$\theta dP_{\max\_ave} = (1 / N) \times \Sigma(\theta dP_{\max} [N])$$

N : Number of cycles

θdPmax : 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)

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

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.  $\theta dP_{max\_Cy\_ave}$** 

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

$$\theta dP_{max\_Cy\_ave} = (1/N) \times \Sigma(\theta dP_{max\_Cy} [N])$$

N : Number of cycles

$\theta dP_{max\_Cy}$  : Averaged crank angle at maximum rate of cylinder pressure rise of all cylinders (CA) (calculated value)

**34. Wpower [N]**

Compression/expansion work (J)

$$\Delta V = \text{abs}(V_{\theta_i} - V_{\theta_{i+1}}) \quad \# \text{ abs: absolute value}$$

$$A[N] = \Sigma (0.5 \times (P_{\theta_i} + P_{\theta_{i+1}}) \times 1000.0 \times \Delta V) \quad \theta = -180 \text{ to } -1$$

$$B[N] = \Sigma (0.5 \times (P_{\theta_i} + P_{\theta_{i+1}}) \times 1000.0 \times \Delta V) \quad \theta = 0 \text{ to } 179$$

$$W_{power}[N] = B[N] - A[N]$$

For a 2-cycle engine, when  $\theta = 179$ ,  $P_{\theta_{i+1}}$  is  $P_{\theta_i}$ , and  $V_{\theta_{i+1}}$  is  $V_{\theta_{-180}}$ .

N : Number of cycles

$V_{\theta}$  : Piston displacement ( $m^3$ ) (calculated value)

$P_{\theta}$  : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

**35. Wpump[N]**

Pumping loss (J)

$$\Delta V = \text{abs}(V_{\theta_i} - V_{\theta_{i+1}}) \quad \# \text{ abs: absolute value}$$

$$C[N] = \Sigma (0.5 \times (P_{\theta_i} + P_{\theta_{i+1}}) \times 1000.0 \times \Delta V) \quad \theta = 180 \text{ to } 359$$

$$D[N] = \Sigma (0.5 \times (P_{\theta_i} + P_{\theta_{i+1}}) \times 1000.0 \times \Delta V) \quad \theta = -360 \text{ to } -181$$

$$W_{pump}[N] = C[N] - D[N]$$

When  $\theta = 359$ ,  $P_{\theta_{i+1}}$  is  $P_{\theta_i}$ , and  $V_{\theta_{i+1}}$  is  $V_{\theta_{-360}}$ .

$W_{pump}[N]$  is zero for 2-cycle engines.

N : Number of cycles

$V_{\theta}$  : Piston displacement ( $m^3$ ) (calculated value)

$P_{\theta}$  : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

**36. Vst**

Piston displacement ( $m^3$ )

$$V_{st} = (\pi / 4) \times B^2 \times S$$

$\pi$  : The circular constant

B : Bore (m) (manually input)

S : Stroke length (m) (manually input)

**37. NMEP[N]**

NMEP (kPa)

$$NMEP[N] = (W_{power} [N] / 1000.0 - W_{pump}[N] / 1000.0) / V_{st}$$

N : Number of cycles

$W_{power}$  : Compression/expansion work (J) (calculated value)

$W_{pump}$  : Pumping loss (J) (calculated value)

$V_{st}$  : Piston displacement ( $m^3$ ) (calculated value)



### 38. NMEP\_ave

Averaged NMEP (kPa)

$$\text{NMEP\_ave} = (1 / N) \times \Sigma(\text{NMEP [N]})$$

N : Number of cycles

NMEP : NMEP (kPa) (calculated value)

### 39. NMEP\_std

Standard deviation of NMEP (kPa)

$$\text{NMEP\_std} = \text{sqrt}((1 / (N-1)) \times \Sigma(\text{NMEP [N]} - \text{NMEP\_ave})^2) \quad \# \text{ sqrt: square root}$$

N : Number of cycles

NMEP : NMEP (kPa) (calculated value)

NMEP\_ave : Averaged NMEP (kPa) (calculated value)

### 40. NMEP\_cov

Rate of change in NMEP (%)

$$\text{NMEP\_cov} = (\text{NMEP\_std} / \text{NMEP\_ave}) \times 100$$

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)

$$\text{NMEP\_Cy[N]} = (1 / \text{Cy}) \times \Sigma(\text{NMEP [Cy, N]})$$

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)

$$\text{NMEP\_Cy\_ave} = (1 / N) \times \Sigma(\text{NMEP\_Cy [N]})$$

N : Number of cycles

NMEP\_Cy : Averaged NMEP of all cylinders (kPa) (calculated value)

### 43. IMEP[N]

IMEP (kPa)

$$\text{IMEP[N]} = (\text{Wpower [N]} / 1000.0) / \text{Vst}$$

N : Number of cycles

Wpower : Compression/expansion work (J) (calculated value)

Vst : Piston displacement (m<sup>3</sup>) (calculated value)

### 44. IMEP\_ave

Averaged IMEP (kPa)

$$\text{IMEP\_ave} = (1 / N) \times \Sigma(\text{IMEP [N]})$$

N : Number of cycles

IMEP : IMEP (kPa) (calculated value)

**45. IMEP\_std**

Standard deviation of IMEP (kPa)

$$\text{IMEP\_std} = \sqrt{(1 / (N-1)) \times \sum(\text{IMEP [N]} - \text{IMEP\_ave})^2} \quad \# \text{ sqrt: square root}$$

N : Number of cycles

IMEP : IMEP (kPa) (calculated value)

IMEP\_ave : Averaged IMEP (kPa) (calculated value)

**46. IMEP\_cov**

Rate of change in IMEP (%)

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

IMEP\_std : Standard deviation of IMEP (kPa) (calculated value)

IMEP\_ave : Averaged IMEP (kPa) (calculated value)

**47. IMEP\_min**

Minimum value of IMEP (kPa)

$$\text{IMEP\_min} = \min(\text{IMEP[N]}) \quad \# \text{ min: minimum value}$$

N : Number of cycles

IMEP : IMEP (kPa) (calculated value)

**48. IMEP\_LNV**

LNV of IMEP (%)

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

IMEP\_min : Minimum value of IMEP (kPa)

IMEP\_ave : Averaged IMEP (kPa) (calculated value)

**49. R\_misfire**

Rate of misfire (%)

$$\text{R\_misfire} = (\text{count}(\text{IMEP[N]} < L) / N) \times 100$$

# 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)

$$\text{IMEP\_Cy[N]} = (1 / \text{Cy}) \times \sum(\text{IMEP [Cy, N]})$$

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)

$$\text{IMEP\_Cy\_ave} = (1 / N) \times \sum(\text{IMEP\_Cy [N]})$$

N : Number of cycles

IMEP\_Cy : Averaged IMEP of all cylinders (kPa) (calculated value)

### 52. PMEP[N]

PMEP (kPa)

$$\text{PMEP}[N] = ((-1 \times W_{\text{pump}} [N]) / 1000.0) / V_{\text{st}}$$

N : Number of cycles  
W<sub>pump</sub> : Pumping loss (J) (calculated value)  
V<sub>st</sub> : Piston displacement (m<sup>3</sup>) (calculated value)

### 53. PMEP\_ave

Averaged PMEP (kPa)

$$\text{PMEP\_ave} = (1 / N) \times \Sigma(\text{PMEP} [N])$$

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

### 54. PMEP\_std

Standard deviation of PMEP (kPa)

$$\text{PMEP\_std} = \text{sqrt}((1 / (N-1)) \times \Sigma(\text{PMEP}[N] - \text{PMEP\_ave})^2) \quad \# \text{ sqrt: square root}$$

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

### 55. PMEP\_cov

Rate of change in PMEP (%)

$$\text{PMEP\_cov} = (\text{PMEP\_std} / \text{PMEP\_ave}) \times 100$$

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)

$$\text{PMEP}[N] = (1 / \text{Cy}) \times \Sigma(\text{IMEP} [\text{Cy}, N])$$

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)

$$\text{PMEP\_Cy\_ave} = (1 / N) \times \Sigma(\text{PMEP\_Cy} [N])$$

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

### 58. T<sub>θ</sub> [720,N], dQ<sub>θ</sub> [720,N], Q<sub>θ</sub> [720,N]

T<sub>θ</sub> [720,N] : Cylinder gas temperature (°C)  
dQ<sub>θ</sub> [720,N] : Rate of heat release (J/deg)  
Q<sub>θ</sub> [720,N] : Amount of heat release (J)

## (1) Gf

Mass of intake fuel (kg)

$$G_f = (G_{fuel} \times (1 / 1000) \times C_v) \times ((60 \times E_{n\_cyl}) / N_e)$$

When fuel consumption and rpm are set to be measured and used in calculations:

$$G_f[N] = (G_{fuel\_ave}[N] \times (1 / 1000) \times C_v) \times ((60 \times E_{n\_cyl}) / N_{e\_ave}[N])$$

N: Number of cycles

G<sub>fuel</sub> : Fuel consumption (cm<sup>3</sup>/sec) (manually input)

Uses average fuel consumption at each cycle when fuel consumption is set to be measured and used in calculations.

$$G_{fuel\_ave}[N] = \text{ave}(G_{fuel}[720, N]) / S_n \quad \# \text{ ave: average value}$$

S<sub>n</sub>: Number of cylinders (used to calculate fuel consumption)

C<sub>v</sub> : Specific gravity (manually input)

E<sub>n\_cyl</sub> : Engine cycle

4-cycle engine: E<sub>n\_cyl</sub> = 2

2-cycle engine: E<sub>n\_cyl</sub> = 1

N<sub>e</sub>: Revolutions per minute (rpm) (manually input)

Uses average rpm at each cycle when rpm is set to be measured and used in calculations.

$$N_{e\_ave}[N] = \text{ave}(N_e[720, N]) \quad \# \text{ ave: average value}$$

(2) G<sub>a</sub>

Mass of intake air (kg)

$$G_a = (V_{eff} / 100) \times ((P_a \times (10000 / 98.0665) \times V_{st}) / (29.27 \times (T_d + 273.16)))$$

When intake manifold pressure and intake manifold temperature are set to be measured and used in calculations:

$$G_a[N] = (V_{eff} / 100) \times ((P_{itk\_ave}[N] \times (10000 / 98.0665) \times V_{st}) / (29.27 \times (T_{d\_ave} + 273.16)))$$

N : Number of cycles

V<sub>eff</sub>: Suction volumetric efficiency (%) (manually input)

P<sub>a</sub> : Atmospheric pressure (kPa) (manually input)

Uses P<sub>itk\_ave</sub>[N] (average intake manifold pressure at each cycle, calculated value) when intake manifold pressure is set to be measured and used in calculations.

V<sub>st</sub> : Piston displacement (m<sup>3</sup>) (calculated value)

T<sub>d</sub> : Atmospheric temperature (°C) (manually input)

Uses the average intake manifold temperature at each cycle when intake manifold temperature is set to be measured and used in calculations.

$$T_{d\_ave}[N] = \text{ave}(T_d[720, N]) \quad \# \text{ ave: average value}$$

## 5.1 Explanation of Equations

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### (3) $\lambda_s$ :

Excess air factor

$$\lambda_s = G_a / (T_{air} \times G_f)$$

When fuel consumption, rpm, intake manifold pressure, and intake manifold temperature are set to be measured and used in calculations:

$$\lambda_s[N] = G_a[N] / (T_{air} \times G_f[N])$$

- G<sub>a</sub>: Mass of intake air (kg) (calculated value)  
Uses G<sub>a</sub>[N] (mass of intake air at each cycle, calculated value) when intake manifold pressure and intake manifold temperature are set to be measured and used in calculations.
- T<sub>air</sub>: Theoretical air (= 14.512 kg)
- G<sub>f</sub>: Mass of intake fuel (kg) (calculated value)  
Uses G<sub>f</sub>[N] (mass of intake fuel at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.

### (4) R<sub>r</sub>

Corrected gas constant

$$GN_2 = (11.211 \times \lambda_s) / (1 + 14.5977 \times \lambda_s)$$

$$GO_2 = (3.3867 \times (\lambda_s - 1)) / (1 + 14.5977 \times \lambda_s)$$

$$GCO_2 = 3.1717 / (1 + 14.5977 \times \lambda_s)$$

$$GH_2O = 1.215 / (1 + 14.5977 \times \lambda_s)$$

$$R_r = (30.26 \times GN_2) + (26.49 \times GO_2) + (19.26 \times GCO_2) + (47.06 \times GH_2O)$$

When fuel consumption, rpm, intake manifold pressure, and intake manifold temperature are set to be measured and used in calculations:

$$GN_2[N] = (11.211 \times \lambda_s[N]) / (1 + 14.5977 \times \lambda_s[N])$$

$$GO_2[N] = (3.3867 \times (\lambda_s[N] - 1)) / (1 + 14.5977 \times \lambda_s[N])$$

$$GCO_2[N] = 3.1717 / (1 + 14.5977 \times \lambda_s[N])$$

$$GH_2O[N] = 1.215 / (1 + 14.5977 \times \lambda_s[N])$$

$$R_r[N] = (30.26 \times GN_2[N]) + (26.49 \times GO_2[N]) + (19.26 \times GCO_2[N]) + (47.06 \times GH_2O[N])$$

- $\lambda_s$ : Excess air factor (calculated value)  
Uses  $\lambda_s[N]$  (excess air factor at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, and intake manifold temperature are set to be measured and used in calculations.

### (5) G<sub>r</sub>

Mass of remaining gas (kg)

Without a supercharger (manually selected)

$$G_r = (P_{ex} \times (10000 / 98.0655) \times V_{st}) / (R_r \times (T_{ex} + 273.16) \times (\epsilon - 1))$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$G_r[N] = (P_{ex\_ave}[N] \times (10000 / 98.0655) \times V_{st}) / (R_r[N] \times (T_{ex\_ave}[N] + 273.16) \times (\epsilon - 1))$$

With a supercharger (manually selected)

$$\alpha = ((T_{turb} + 273.16) / 1.1 - (T_{boost} + 273.16)) / (T_{turb} - T_{boost})$$

$$(\alpha = 0.9 \text{ when } \alpha > 0.9)$$

$$G_r = ((1 - \alpha) \times P_{turb} \times (10000 / 98.0655) \times V_{st}) / (R_r \times (T_{turb} + 273.16) \times (\epsilon - 1))$$

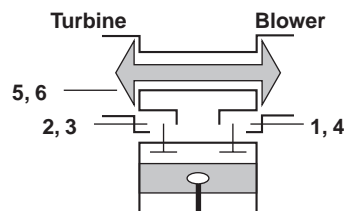
When the fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, and boost temperature (intake manifold temperature) are set to be measured and used in calculations:

$$\alpha[N] = ((T_{\text{turb\_ave}}[N] + 273.16) / 1.1 - (T_{\text{d\_ave}}[N] + 273.16)) / (T_{\text{turb\_ave}}[N] - T_{\text{d\_ave}}[N])$$

$$(\alpha[N] = 0.9 \text{ when } \alpha[N] > 0.9)$$

$$Gr[N] = ((1 - \alpha[N]) \times P_{\text{turb\_ave}}[N] \times (10000 / 98.0655) \times V_{\text{st}}) / (R_r[N] \times (T_{\text{turb\_ave}}[N] + 273.16) \times (\epsilon - 1))$$

Pex:	Exhaust gas pressure (kPa) (manually input) Uses average exhaust gas pressure at each cycle when exhaust gas pressure is set to be measured and used in calculations. $P_{\text{ex\_ave}}[N] = \text{ave}(P_{\text{ex}}[720, N])$ # <i>ave: average value</i>
Vst:	Piston displacement (m <sup>3</sup> ) (calculated value)
Rr:	Corrected gas constant (calculated value) Uses $R_r[N]$ (corrected gas constant for each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, and intake manifold temperature are set to be measured and used in calculations.
Tex:	Exhaust gas temperature (°C) (manually input) Uses average exhaust gas temperature at each cycle when exhaust gas temperature is set to be measured and used in calculations. $T_{\text{ex\_ave}}[N] = \text{ave}(T_{\text{ex}}[720, N])$ # <i>ave: average value</i>
ε:	Compression ratio (manually input)
Tturb:	Supercharger inlet temperature (°C) (manually input) Uses average supercharger inlet temperature at each cycle when supercharger inlet temperature is set to be measured and used in calculations. $T_{\text{turb\_ave}}[N] = \text{ave}(T_{\text{turb}}[720, N])$ # <i>ave: average value</i>
Tboost:	Boost temperature (°C) (manually input) Uses average intake manifold temperature at each cycle when intake manifold temperature is set to be measured and used in calculations. $T_{\text{d\_ave}}[N] = \text{ave}(T_{\text{d}}[720, N])$ # <i>ave: average value</i>
Pturb:	Supercharger inlet pressure (kPa) (manually input) Uses average supercharger inlet pressure at each cycle when supercharger inlet pressure is set to be measured and used in calculations. $P_{\text{turb\_ave}}[N] = \text{ave}(P_{\text{turb}}[720, N])$ # <i>ave: average value</i>



1. Boost pressure ( $P_t$ )
2. Supercharger inlet pressure ( $P_{\text{turb}}$ )
3. Supercharger inlet temperature ( $T_{\text{turb}}$ )
4. Boost temperature ( $T_{\text{boost}}$ )
5. Exhaust gas pressure ( $P_{\text{ex}}$ )
6. Exhaust gas temperature ( $T_{\text{ex}}$ )

### (6) Initial Values (–360 CA (–180 CA for 2–Cycle Engines) – Point a: Start Point of Heat Release)

Repeatedly calculates from (6–1) to (6–6) for the interval as follows:

From  $\theta = -360\text{CA}$  (–180CA for 2–cycle engine) to the crank angle (point a) at which  $dQ_\theta$  changes to a positive value immediately before  $dQ_\theta$  becomes  $dQ_{\max}$  (the maximum value of  $dQ_\theta$ ).

#### (6–1) $T_\theta [\theta, N]$

Gas temperature (K)

$$G_{t0} = G_a + G_r$$

$$G_{ab} = G_a + G_r \times (1 - G_f / G_a)$$

$$G_{rb} = G_r \times G_f / G_a$$

$$\lambda_{amo} = G_{ab} / (Th_{air} \times G_{rb})$$

$$R_0 = R - (0.14 / \lambda_{amo})$$

$$T_\theta [\theta, N] = P_\theta [\theta, N] \times (10000 / 98.0665) \times V_\theta [\theta] / (G_{t0} \times R_0)$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$G_{t0}[N] = G_a[N] + G_r[N]$$

$$G_{ab}[N] = G_a[N] + G_r[N] \times (1 - G_f[N] / G_a[N])$$

$$G_{rb}[N] = G_r[N] \times G_f[N] / G_a[N]$$

$$\lambda_{amo}[N] = G_{ab}[N] / (Th_{air} \times G_{rb}[N])$$

$$R_0[N] = R - (0.14 / \lambda_{amo}[N])$$

$$T_\theta [\theta, N] = P_\theta [\theta, N] \times (10000 / 98.0665) \times V_\theta [\theta] / (G_{t0}[N] \times R_0[N])$$

$G_{t0}$ : Total mass of gas (kg)

$G_a$ : Mass of intake air (kg) (calculated value)  
Uses  $G_a[N]$  (mass of intake air at each cycle, calculated value) when intake manifold pressure and intake manifold temperature are set to be measured and used in calculations.

$G_r$ : Mass of remaining gas (kg) (manually input)  
Uses  $G_r[N]$  (mass of remaining gas at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, supercharger inlet temperature, and boost temperature (intake manifold temperature) are set to be measured and used in calculations.

$G_f$ : Mass of intake fuel (kg) (calculated value)  
Uses  $G_f[N]$  (mass of intake fuel at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.

$\lambda_{amo}$ : Average excess air factor

$Th_{air}$ : Theoretical air (= 14.512 kg)

$R$ : Gas constant (= 29.27) ( $\times 9.80665 \text{ J/kg.K}$ ) (manually input)

$P_\theta$ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

$V_\theta$ : Piston displacement ( $\text{m}^3$ ) (calculated value)

**(6-2)  $\kappa_\theta$  [ $\theta, N$ ]**

Ratio of specific heat

$$\kappa_\theta [\theta, N] = 1.4373 - 1.318 \times 10^{-4} \times T_\theta [\theta, N] + 3.12 \times 10^{-8} \times T_\theta [\theta, N]^2 - 4.8 \times 10^{-2} / \lambda_{amo}$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$\kappa_\theta [\theta, N] = 1.4373 - 1.318 \times 10^{-4} \times T_\theta [\theta, N] + 3.12 \times 10^{-8} \times T_\theta [\theta, N]^2 - 4.8 \times 10^{-2} / \lambda_{amo}[N]$$

$T_\theta$  : Gas temperature (K) (calculated value)

$\lambda_{amo}$ : Average excess air factor (calculated value)

Uses  $\lambda_{amo}[N]$  (average excess air factor at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations.

**(6-3)  $dQ_{reci\theta}$  [ $\theta, N$ ]**

Rate of heat release (received heat) (J/deg)

$$dQ_{reci\theta} [\theta, N] = \kappa_\theta [\theta, N] / (\kappa_\theta [\theta, N] - 1) \times P_\theta [\theta, N] \times 1000.0 \times dV_\theta [\theta] + 1 / (\kappa_\theta [\theta, N] - 1) \times dP_\theta [\theta, N] \times 1000.0 \times V_\theta [\theta]$$

$\kappa_\theta$ : Rate of specific heat (calculated value)

$P_\theta$  : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

$dV_\theta$  : Rate of cylinder volume increase (m<sup>3</sup>/deg) (calculated value)

$V_\theta$ : Piston displacement (m<sup>3</sup>) (calculated value)

$dP_\theta$  : Rate of cylinder pressure rise (kPa/deg) (calculated value)

**(6-4)  $dQ_{wi\theta}$** 

Rate of heat release (heat loss) (J/deg)

When taking heat loss into account (manually select)

$$C_m = 2 \times S \times N_e / 60$$

$$Sh = B^2 \times \pi / 4$$

$$Sp = PistHr \times Sh$$

$$F_\theta [\theta] = (V_\theta [\theta] / Sh) \times \pi \times B$$

$$dQ_{wig\theta} [\theta, N] = 256 \times B^{-0.124} \times (C_m \times P_\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T_\theta [\theta, N]^{-0.525})$$

$$T_{wall\_K} = T_{wall} + 273.16$$

$$dQ_{wisl\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wall\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wall\_K})$$

$$T_{wallH\_K} = T_{wallH} + 273.16$$

$$dQ_{wish\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wallH\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wallH\_K})$$

$$T_{wallP\_K} = T_{wallP} + 273.16$$

$$dQ_{wisp\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wallP\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wallP\_K})$$

$$dQ_{wi\theta} [\theta, N] = (((dQ_{wig\theta} [\theta, N] + dQ_{wisl\theta} [\theta, N]) \times F_\theta [\theta] \times (T_\theta [\theta, N] - T_{wall\_K})$$

$$+ dQ_{wish\theta} [\theta, N] \times Sh \times (T_\theta [\theta, N] - T_{wallH\_K}) + dQ_{wig\theta} [\theta, N]$$

$$+ dQ_{wisp\theta} [\theta, N]) \times Sp \times (T_\theta [\theta, N] - T_{wallP\_K}) / (6 \times N_e \times 3600)) \times 4.18605 \times 10^3$$



## 5.1 Explanation of Equations

When rpm is set to be measured and used in calculations:

$$Cm[N] = 2 \times S \times Ne\_ave[N] / 60$$

$$Sh = B^2 \times \pi / 4$$

$$Sp = PistHr \times Sh$$

$$F\theta [\theta] = (V\theta [\theta] / Sh) \times \pi \times B$$

$$dQwig\theta [\theta, N] = 256 \times B^{-0.124} \times (Cm[N] \times P\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T\theta [\theta, N])^{-0.525}$$

$$Twall\_K = Twall + 273.16$$

$$dQwisl\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (Twall\_K / 100)^4) / (T\theta [\theta, N] - Twall\_K)$$

$$TwallH\_K = TwallH + 273.16$$

$$dQwish\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (TwallH\_K / 100)^4) / (T\theta [\theta, N] - TwallH\_K)$$

$$TwallP\_K = TwallP + 273.16$$

$$dQwisp\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (TwallP\_K / 100)^4) / (T\theta [\theta, N] - TwallP\_K)$$

$$dQwi\theta [\theta, N] = (((dQwig\theta [\theta, N] + dQwisl\theta [\theta, N]) \times F\theta [\theta] \times (T\theta [\theta, N] - Twall\_K) + dQwig\theta [\theta, N] + dQwish\theta [\theta, N]) \times Sh \times (T\theta [\theta, N] - TwallH\_K) + dQwig\theta [\theta, N] + dQwisp\theta [\theta, N]) \times Sp \times (T\theta [\theta, N] - TwallP\_K)) / (6 \times Ne\_ave[N] \times 3600)) \times 4.18605 \times 10^3$$

When not taking heat loss into account

$$dQwi\theta [\theta] = 0$$

Cm:	Average piston speed (m/s) Uses Cm[N] (average piston speed at each cycle) when rpm is set to be measured and used in calculations.
S:	Stroke (m) (manually input)
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
Sh:	Cylinder cross-sectional area (m <sup>2</sup> )
B:	Bore (m) (manually input)
pi:	The circular constant
Sp:	Area of the piston head (m <sup>2</sup> ) (manually input)
PistHr:	Piston head ratio (manually input)
Fθ:	Cylinder clearance (m <sup>2</sup> )
Vθ:	Piston displacement (m <sup>3</sup> ) (calculated value)
Twall:	Cylinder wall temperature (°C) (manually input)
Tθ :	Gas temperature (K) (calculated value)
TwallH:	Cylinder head wall temperature (°C) (manually input)
TwallP:	Piston head wall temperature (°C) (manually input)

### (6-5) dQθ

Rate of heat release (J/deg)

$$dQ\theta [\theta, N] = dQreci\theta [\theta, N] + dQwi\theta [\theta, N]$$

dQreciθ:	Rate of heat release (received heat) (J/deg) (calculated value)
dQwiθ:	Rate of heat release (heat loss) (J/deg) (calculated value)

### (6-6) Qθ [θ, N]

Amount of heat release (J)

$$Q\theta [\theta, N] = 0$$

## (7) Combustion Period (Point a: Start Point of Heat Release to Point b: End Point of Heat Release)

Repeatedly calculates from (7-1) to (7-6) until the following conditions are satisfied:  
From  $\theta$  = point a until the crank angle at which  $dQ_{\theta}$  changes to a negative value immediately after  $dQ_{\theta}$  becomes  $dQ_{\max}$  (the maximum value of  $dQ_{\theta}$ ). Use the value for  $Q_{\text{prev}\theta}$  in (7-5) in (7-5).

$$Q_0 = G_f \times H_u$$

$$Q_{\text{prev}\theta} = 0$$

$H_u$  : Amount of heat release at the lowest position (J/kg) (manually input)

$G_f$  : Mass of intake fuel (kg) (calculated value)

$Q_{\text{prev}\theta}$  : Amount of heat release at the current angle (J)

### (7-1) $T_{\theta}$

Gas temperature (K)

$$G_{ab} = G_a + G_r \times (1 - G_f / G_a)$$

$$G_{rb} = G_r \times G_f / G_a$$

$$G_{t0\theta} = G_{ab} + G_{rb} + Q_{\text{prev}\theta} / H_u$$

$$\lambda_{a\theta} = G_{ab} / (T_{\text{hair}} \times (G_{rb} + Q_{\text{prev}\theta} / H_u))$$

$$R_{0\theta} = R - (0.14 / \lambda_{a\theta})$$

$$T_{\theta} [\theta, N] = P_{\theta} [\theta, N] \times (10000 / 98.0665) \times V_{\theta} [\theta] / (G_{t0\theta} \times R_{0\theta})$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$G_{ab}[N] = G_a[N] + G_r[N] \times (1 - G_f[N] / G_a[N])$$

$$G_{rb}[N] = G_r[N] \times G_f[N] / G_a[N]$$

$$G_{t0\theta} [N] = G_{ab}[N] + G_{rb}[N] + Q_{\text{prev}\theta} / H_u$$

$$\lambda_{a\theta}[N] = G_{ab}[N] / (T_{\text{hair}} \times (G_{rb}[N] + Q_{\text{prev}\theta} / H_u))$$

$$R_{0\theta}[N] = R - (0.14 / \lambda_{a\theta}[N])$$

$$T_{\theta} [\theta, N] = P_{\theta} [\theta, N] \times (10000 / 98.0665) \times V_{\theta} [\theta] / (G_{t0\theta}[N] \times R_{0\theta}[N])$$

$G_a$  : Mass of intake air (kg) (calculated value)

Uses  $G_a[N]$  (mass of intake air at each cycle, calculated value) when intake manifold pressure and intake manifold temperature are set to be measured and used in calculations.

$G_r$  : Mass of remaining gas (kg) (calculated value)

Uses  $G_r[N]$  (mass of remaining gas at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, supercharger inlet temperature, and boost temperature (intake manifold temperature) are set to be measured and used in calculations.

$G_f$  : Mass of intake fuel (kg) (calculated value)

Uses  $G_f[N]$  (mass of intake fuel at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.

$Q_{\text{prev}}$  : Amount of heat release at the current angle (J) (calculated value)

$H_u$  : Amount of heat release at the lowest position (J/kg) (manually input)

## 5.1 Explanation of Equations

Thair:	Theoretical air (= 14.512 kg)
R:	Gas constant (= 29.27) (× 9.80665 J/kg.K) (manually input)
Pθ:	Cylinder pressure (kPa) after absolute pressure correction (calculated value)
Vθ:	Piston displacement (m <sup>3</sup> ) (calculated value)

### (7-2) κθ [θ,N]

Ratio of specific heat

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

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

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

Tθ :	Gas temperature (K) (calculated)
λ <sub>amo</sub> θ:	Average excess air factor (calculated value) Uses λ <sub>amo</sub> [N] (average excess air factor at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations.

### (7-3) dQreci

Rate of heat release (received heat) (J/deg)

$$dQ_{reci}[\theta, N] = \kappa\theta [\theta, N] / (\kappa\theta [\theta, N] - 1) \times P\theta [\theta, N] \times 1000.0 \times dV\theta [\theta] + 1 / (\kappa\theta [\theta, N] - 1) \times dP\theta [\theta, N] \times 1000.0 \times V\theta [\theta]$$

κθ:	Ratio of specific heat
Pθ :	Cylinder pressure (kPa) after absolute pressure correction (calculated value)
Vθ:	Piston displacement (m <sup>3</sup> ) (calculated value)

### (7-4) dQwiθ [θ,N]

Rate of heat release (heat loss) (J/deg)

When taking heat loss into account (manually select)

$$C_m = 2 \times S \times N_e / 60$$

$$F\theta [\theta] = (V\theta [\theta] / Sh) \times \pi \times B$$

$$dQ_{wig\theta} [\theta, N] = 256 \times B^{-0.124} \times (C_m \times P\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T\theta [\theta, N]^{-0.525})$$

$$T_{wall\_K} = T_{wall} + 273.16$$

$$dQ_{wisl\theta} [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (T_{wall\_K} / 100)^4) / (T\theta [\theta, N] - T_{wall\_K})$$

$$T_{wallH\_K} = T_{wallH} + 273.16$$

$$dQ_{wish\theta} [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (T_{wallH\_K} / 100)^4) / (T\theta [\theta, N] - T_{wallH\_K})$$

$$T_{wallP\_K} = T_{wallP} + 273.16$$

$$dQ_{wisp\theta} [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (T_{wallP\_K} / 100)^4) / (T\theta [\theta, N] - T_{wallP\_K})$$

$$dQ_{wi\theta} [\theta, N] = (((dQ_{wig\theta} [\theta, N] + dQ_{wisl\theta} [\theta, N]) \times F\theta [\theta] \times (T\theta [\theta, N] - T_{wall\_K}) + (dQ_{wig\theta} [\theta, N] + dQ_{wish\theta} [\theta, N]) \times Sh \times (T\theta [\theta, N] - T_{wallH\_K}) + (dQ_{wig\theta} [\theta, N] + dQ_{wisp\theta} [\theta, N]) \times S_p \times (T\theta [\theta, N] - T_{wallP\_K})) / (6 \times N_e \times 3600)) \times 4.18605 \times 10^3$$

When rpm is set to be measured and used in calculations:

$$Cm[N] = 2 \times S \times Ne\_ave[N] / 60$$

$$F\theta [\theta] = (V\theta [\theta] / Sh) \times \pi \times B$$

$$dQwig\theta [\theta, N] = 256 \times B^{-0.124} \times (Cm[N] \times P\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T\theta [\theta, N])^{-0.525}$$

$$Twall\_K = Twall + 273.16$$

$$dQwisl\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (Twall\_K / 100)^4) / (T\theta [\theta, N] - Twall\_K)$$

$$TwallH\_K = TwallH + 273.16$$

$$dQwish\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (TwallH\_K / 100)^4) / (T\theta [\theta, N] - TwallH\_K)$$

$$TwallP\_K = TwallP + 273.16$$

$$dQwisp\theta [\theta, N] = 0.362 \times ((T\theta [\theta, N] / 100)^4 - (TwallP\_K / 100)^4) / (T\theta [\theta, N] - TwallP\_K)$$

$$dQwi\theta [\theta, N] = (((dQwig\theta [\theta, N] + dQwisl\theta [\theta, N]) \times F\theta [\theta] \times (T\theta [\theta, N] - Twall\_K) + (dQwig\theta [\theta, N] + dQwish\theta [\theta, N]) \times Sh \times (T\theta [\theta, N] - TwallH\_K) + (dQwig\theta [\theta, N] + dQwisp\theta [\theta, N]) \times Sp \times (T\theta [\theta, N] - TwallP\_K)) / (6 \times Ne\_ave[N] \times 3600)) \times 4.18605 \times 10^3$$

When not taking heat loss into account

$$dQwi[\theta] = 0$$

Cm:	Average piston speed (m/s) Uses Cm[N] (average piston speed at each cycle) when rpm is set to be measured and used in calculations.
S:	Stroke (m) (manually input)
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
Vθ:	Piston displacement (m <sup>3</sup> ) (calculated value)
Sh:	Cylinder cross-sectional area (m <sup>2</sup> )
B:	Bore (m) (manually input)
pi:	The circular constant
Fθ:	Cylinder clearance (m <sup>2</sup> )
Sp:	Area of the piston head (m <sup>2</sup> ) (manually input)
Twall:	Cylinder wall temperature (°C) (manually input)
Tθ :	Gas temperature (K) (calculated value)
TwallH:	Cylinder head wall temperature (°C) (manually input)
TwallP:	Piston head wall temperature (°C) (manually input)

## (7-5) dQθ

Rate of heat release (J/deg)

$$dQ\theta [\theta, N] = dQreci\theta [\theta, N] + dQwi\theta [\theta, N]$$

$$Qprev\theta = Qprev\theta + dQ\theta [\theta, N] \times res$$

When  $Qprev\theta > Q0$ ,  $Qprev\theta = Q0$ .

For  $dQ\theta \leq 0$ , do not add.

dQreciθ:	Rate of heat release (received heat) (J/deg) (calculated value)
dQwiθ:	Rate of heat release (heat loss) (J/deg) (calculated value)
res:	Angle resolution (manually input)
Qprevθ:	Amount of heat release at the current angle (J)
Q0:	= Gf × Hu Uses Gf[N] (mass of intakefuel at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.

### (7-6) $Q_{\theta}$ [6,N]

Amount of heat release (J)

$$Q_{\theta} [0,N] = Q_{prev\theta}$$

$Q_{prev\theta}$ : Amount of heat release at the current angle (J)

### (8) From the End Point of Heat Release (Point b: End Point of Heat Release to +360 CA (+180 CA for 2-Cycle Engines) )

Repeatedly calculates from (8-1) to (8-6) from  $q$  = point b to +360 CA (+180 CA for 2-cycle engines)

$$Q_0 = Q_{\theta} [b,N]$$

$Q_{\theta} [b,N]$ : Amount of heat release at point b (J)

### (8-1) $T_{\theta}$

Gas temperature (K)

$$G_{ab} = G_a + G_r \times (1 - G_f / G_a)$$

$$G_{rb} = G_r \times G_f / G_a$$

$$G_{t0} = G_{ab} + G_{rb} + Q_0 / H_u$$

$$\lambda_{amo} = G_{ab} / (T_{hair} \times (G_{rb} + Q_0 / H_u))$$

$$R_0 = R - (0.14 / \lambda_{amo})$$

$$T_{\theta} [\theta,N] = P_{\theta} [\theta,N] \times (10000 / 98.0665) \times V_{\theta} [\theta] / (G_{t0} \times R_0)$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$G_{ab}[N] = G_a[N] + G_r[N] \times (1 - G_f[N] / G_a[N])$$

$$G_{rb}[N] = G_r[N] \times G_f[N] / G_a[N]$$

$$G_{t0}[N] = G_{ab}[N] + G_{rb}[N] + Q_0 / H_u$$

$$\lambda_{amo}[N] = G_{ab}[N] / (T_{hair} \times (G_{rb}[N] + Q_0 / H_u))$$

$$R_0[N] = R - (0.14 / \lambda_{amo}[N])$$

$$T_{\theta} [\theta,N] = P_{\theta} [\theta,N] \times (10000 / 98.0665) \times V_{\theta} [\theta] / (G_{t0}[N] \times R_0[N])$$

$G_a$ : Mass of intake air (kg) (calculated value)  
Uses  $G_a[N]$  (mass of intake air at each cycle, calculated value) when intake manifold pressure and intake manifold temperature are set to be measured and used in calculations.

$G_r$ : Mass of remaining gas (kg) (calculated value)  
Uses  $G_r[N]$  (mass of remaining gas at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, exhaust gas pressure, exhaust gas temperature, supercharger inlet pressure, supercharger inlet temperature, and boost temperature (intake manifold temperature) are set to be measured and used in calculations.

$G_f$ : Mass of intake fuel (kg) (calculated value)  
Uses  $G_f[N]$  (mass of intake fuel at each cycle, calculated value) when fuel consumption and rpm are set to be measured and used in calculations.

$Q_0$ : Amount of heat release at point b (J) (calculated value)

$H_u$ : Amount of heat release at the lowest position (J/kg) (manually input)

$T_{hair}$ : Theoretical air (= 14.512 kg)

$R$ : Gas constant (= 29.27) ( $\times 9.80665$  J/kg K) (manually input)

$P_{\theta}$ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

$V_{\theta}$ : Piston displacement ( $m^3$ ) (calculated value)

**(8-2)  $\kappa_\theta$  [ $\theta, N$ ]**

Ratio of specific heat

$$\kappa_\theta [\theta, N] = 1.4373 - 1.318 \times 10^{-4} \times T_\theta [\theta, N] + 3.12 \times 10^{-8} \times T_\theta [\theta, N]^2 - 4.8 \times 10^{-2} / \lambda_{amo}$$

When fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations:

$$\kappa_\theta [\theta, N] = 1.4373 - 1.318 \times 10^{-4} \times T_\theta [\theta, N] + 3.12 \times 10^{-8} \times T_\theta [\theta, N]^2 - 4.8 \times 10^{-2} / \lambda_{amo}[N]$$

$T_\theta$  : Gas temperature (K) (calculated value)

$\lambda_{amo}$ : Average excess air factor (calculated value)

Uses  $\lambda_{amo}[N]$  (average excess air factor at each cycle, calculated value) when fuel consumption, rpm, intake manifold pressure, intake manifold temperature, supercharger inlet pressure, supercharger inlet temperature, boost temperature (intake manifold temperature), exhaust gas pressure, and exhaust gas temperature are set to be measured and used in calculations.

**(8-3)  $dQ_{reci}$** 

Rate of heat release (received heat) (J/deg)

$$dQ_{reci} [\theta, N] = \kappa_\theta [\theta, N] / (\kappa_\theta [\theta, N] - 1) \times P_\theta [\theta, N] \times 1000.0 \times dV_\theta [\theta] + 1 / (\kappa_\theta [\theta, N] - 1) \times dP_\theta [\theta, N] \times 1000.0 \times V_\theta [\theta]$$

$\kappa_\theta$ : Ratio of specific heat

$P_\theta$ : Cylinder pressure (kPa) after absolute pressure correction (calculated value)

$V_\theta$ : Piston displacement ( $m^3$ ) (calculated value)

**(8-4)  $dQ_{wi\theta}$  [ $\theta, N$ ]**

Rate of heat release (heat loss) (J/deg)

When taking heat loss into account (manually select)

$$C_m = 2 \times S \times N_e / 60$$

$$F_\theta [\theta] = (V_\theta [\theta] / S_h) \times \pi \times B$$

$$dQ_{wig\theta} [\theta, N] = 256 \times B^{-0.124} \times (C_m \times P_\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T_\theta [\theta, N])^{-0.525}$$

$$T_{wall\_K} = T_{wall} + 273.16$$

$$dQ_{wisl\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wall\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wall\_K})$$

$$T_{wallH\_K} = T_{wallH} + 273.16$$

$$dQ_{wish\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wallH\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wallH\_K})$$

$$T_{wallP\_K} = T_{wallP} + 273.16$$

$$dQ_{wisp\theta} [\theta, N] = 0.362 \times ((T_\theta [\theta, N] / 100)^4 - (T_{wallP\_K} / 100)^4) / (T_\theta [\theta, N] - T_{wallP\_K})$$

$$dQ_{wi\theta} [\theta, N] = (((dQ_{wig\theta} [\theta, N] + dQ_{wisl\theta} [\theta, N]) \times F_\theta [\theta] \times (T_\theta [\theta, N] - T_{wall\_K}) + (dQ_{wig\theta} [\theta, N] + dQ_{wish\theta} [\theta, N]) \times S_h \times (T_\theta [\theta, N] - T_{wallH\_K}) + (dQ_{wig\theta} [\theta, N] + dQ_{wisp\theta} [\theta, N]) \times S_p \times (T_\theta [\theta, N] - T_{wallP\_K})) / (6 \times N_e \times 3600)) \times 4.18605 \times 10^3$$

When rpm is set to be measured and used in calculations:

$$C_m[N] = 2 \times S \times N_{e\_ave}[N] / 60$$

$$F_\theta [\theta] = (V_\theta [\theta] / S_h) \times \pi \times B$$

$$dQ_{wig\theta} [\theta, N] = 256 \times B^{-0.124} \times (C_m[N] \times P_\theta [\theta, N] / (10000 / 98.0665))^{0.786} \times (T_\theta [\theta, N])^{-0.525}$$

## 5.1 Explanation of Equations

$$\begin{aligned}
 T_{wall\_K} &= T_{wall} + 273.16 \\
 dQ_{wisl\theta} [\theta, N] &= 0.362 \times ((T_{\theta} [\theta, N] / 100)^4 - (T_{wall\_K} / 100)^4) / (T_{\theta} [\theta, N] - T_{wall\_K}) \\
 T_{wallH\_K} &= T_{wallH} + 273.16 \\
 dQ_{wish\theta} [\theta, N] &= 0.362 \times ((T_{\theta} [\theta, N] / 100)^4 - (T_{wallH\_K} / 100)^4) / (T_{\theta} [\theta, N] - T_{wallH\_K}) \\
 T_{wallP\_K} &= T_{wallP} + 273.16 \\
 dQ_{wisp\theta} [\theta, N] &= 0.362 \times ((T_{\theta} [\theta, N] / 100)^4 - (T_{wallP\_K} / 100)^4) / (T_{\theta} [\theta, N] - T_{wallP\_K}) \\
 dQ_{wi\theta} [\theta, N] &= (((dQ_{wig\theta} [\theta, N] + dQ_{wisl\theta} [\theta, N]) \times F_{\theta} [\theta] \times (T_{\theta} [\theta, N] - T_{wall\_K}) \\
 &\quad + (dQ_{wig\theta} [\theta, N] + dQ_{wish\theta} [\theta, N]) \times Sh \times (T_{\theta} [\theta, N] - T_{wallH\_K}) + (dQ_{wig\theta} [\theta, N] \\
 &\quad + dQ_{wisp\theta} [\theta, N]) \times Sp \times (T_{\theta} [\theta, N] - T_{wallP\_K})) / (6 \times Ne\_ave[N] \times 3600)) \\
 &\quad \times 4.18605 \times 10^3
 \end{aligned}$$

When not taking heat loss into account

$$dQ_{wi}[\theta] = 0$$

Cm:	Average piston speed (m/s) Uses Cm[N] (average piston speed at each cycle) when rpm is set to be measured and used in calculations.
S:	Stroke (m) (manually input)
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
V $\theta$ :	Cylinder volume (m <sup>3</sup> ) (calculated value)
Sh:	Cylinder cross-sectional area (m <sup>2</sup> )
B:	Bore (m) (manually input)
pi:	The circular constant
F $\theta$ :	Cylinder clearance (m <sup>2</sup> )
Sp:	Area of the piston head (m <sup>2</sup> ) (manually input)
T <sub>wall</sub> :	Cylinder wall temperature (°C) (manually input)
T $\theta$ :	Gas temperature (K) (calculated value)
T <sub>wallH</sub> :	Cylinder head wall temperature (°C) (manually input)
T <sub>wallP</sub> :	Piston head wall temperature (°C) (manually input)

### (8-5) dQ $\theta$

Rate of heat release (J/deg)

$$dQ_{\theta} [\theta, N] = dQ_{reci\theta} [\theta, N] + dQ_{wi\theta} [\theta, N]$$

dQ <sub>reci</sub> $\theta$ :	Rate of heat release (received heat) (J/deg) (calculated value)
dQ <sub>wi</sub> $\theta$ :	Rate of heat release (heat loss) (J/deg) (calculated value)

### (8-6) Q $\theta$ [ $\theta$ , N]

Amount of heat release (J)

$$Q_{\theta} [\theta, N] = Q_0$$

Q <sub>0</sub> :	Amount of heat release at point b (J)
------------------	---------------------------------------

### (9) T $\theta$

Cylinder gas temperature (°C)

$$T_{\theta} [720, N] = T_{\theta} [720, N] - 273.16$$

T $\theta$ :	Gas temperature (K) (calculated value)
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**59.  $T_{\theta}$  ave[720]**

Average cylinder gas temperature (°C)

$$T_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(T_{\theta} [720, N])$$

N : Number of cycles

 $T_{\theta}$  : Cylinder gas temperature (°C) (calculated value)**60. Tmax[N]**

Maximum cylinder gas temperature (°C)

$$T_{\max}[N] = \max(T_{\theta} [720, N])$$

N : Number of cycles

 $T_{\theta}$  : Cylinder gas temperature (°C) (calculated value)**61.  $\theta T_{\max}[N]$** 

Crank angle (CA) at maximum cylinder gas temperature

$$\theta T_{\max}[N] = \text{pos}(T_{\theta} [720, N]) \quad \# \text{ pos: crank angle at the maximum cylinder gas temperature}$$

N : Number of cycles

 $T_{\theta}$  : Cylinder gas temperature (°C) (calculated value)**62. Tmax\_ave**

Averaged maximum cylinder gas temperature (°C)

$$T_{\max\_ave} = (1 / N) \times \Sigma(T_{\max} [N])$$

N : Number of cycles

 $T_{\max}$  : Maximum cylinder gas temperature (°C) (calculated value)**63. Tmax\_std**

Standard deviation of maximum cylinder gas temperature (°C)

$$T_{\max\_std} = \sqrt{(1 / (N-1)) \times \Sigma(T_{\max} [N] - T_{\max\_ave})^2} \quad \# \text{ sqrt: square root}$$

N : Number of cycles

 $T_{\max}$  : Maximum cylinder gas temperature (°C) (calculated value) $T_{\max\_ave}$  : Averaged maximum cylinder gas temperature (°C) (calculated value)**64. Tmax\_cov**

Rate of change in maximum cylinder gas temperature (%)

$$T_{\max\_cov} = (T_{\max\_std} / T_{\max\_ave}) \times 100$$

 $T_{\max\_std}$  : Standard deviation of maximum cylinder gas temperature (°C) (calculated value) $T_{\max\_ave}$  : Averaged maximum cylinder gas temperature (°C) (calculated value)**65. dQ $\theta$  ave [720]**

Average rate of heat release (J/deg)

$$dQ_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(dQ_{\theta} [720, N])$$

N : Number of cycles

 $dQ_{\theta}$  : Rate of heat release (J/deg) (calculated value)



### 66. dQmax[N]

Maximum rate of heat release (J/deg)

$$dQ_{\max}[N] = \max(dQ_{\theta} [720, N])$$

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

N : Number of cycles

dQ $\theta$  : Rate of heat release (J/deg) (calculated value)

### 67. $\theta dQ_{\max}[N]$

Crank angle at maximum rate of heat release (CA)

$$\theta dQ_{\max}[N] = \text{pos}(dQ_{\theta} [720, N]) \quad \# \text{ pos: crank angle at maximum rate of heat release}$$

N : Number of cycles

dQ $\theta$  : Rate of heat release (J/deg) (calculated value)

### 68. $\theta dQ_{\max\_ave}$

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

$$\theta dQ_{\max\_ave} = (1 / N) \times \Sigma(\theta dQ_{\max} [N])$$

N : Number of cycles

$\theta dQ_{\max}$  : Crank angle at maximum rate of heat release (CA) (calculated value)

### 69. dQmax\_ave

Averaged maximum rate of heat release (J/deg)

$$dQ_{\max\_ave} = (1 / N) \times \Sigma(dQ_{\max} [N])$$

N: Number of cycles

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

### 70. dQmax\_std

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

$$dQ_{\max\_std} = \sqrt{(1 / (N-1)) \times \Sigma(dQ_{\max} [N] - dQ_{\max\_ave})^2} \quad \# \text{ sqrt: square root}$$

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)

### 71. dQmax\_cov

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

$$dQ_{\max\_cov} = (dQ_{\max\_std} / dQ_{\max\_ave}) \times 100$$

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)

### 72. Q $\theta$ ave [720]

Average amount of heat release (J)

$$Q_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(Q_{\theta} [720, N])$$

N : Number of cycles

Q $\theta$  : Amount of heat release (J) (calculated value)

**73. Qmax [N]**

Maximum amount of heat release (J)

$$Q_{\max}[N] = \max(Q_{\theta} [720, N]) \quad \# \text{ max: maximum value}$$

N : Number of cycles

Q $\theta$  : Amount of heat release (J) (calculated value)

**74.  $\theta Q_{\max}$  [N]**

Crank angle (CA) at maximum amount of heat release

$$\theta Q_{\max}[N] = \text{pos}(Q_{\theta} [720, N]) \quad \# \text{ pos: crank angle at the maximum amount of heat release}$$

N : Number of cycles

Q $\theta$  : Amount of heat release (J) (calculated value)

**75.  $\theta Q_{\max\_ave}$** 

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

$$\theta Q_{\max\_ave} = (1 / N) \times \Sigma(\theta Q_{\max} [N])$$

N : Number of cycles

$\theta Q_{\max}$  : Crank angle at maximum amount of heat release (CA) (calculated value)

**76. Qmax\_ave**

Averaged maximum amount of heat release (J)

$$Q_{\max\_ave} = (1 / N) \times \Sigma(Q_{\max} [N])$$

N : Number of cycles

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

**77. Qmax\_std**

Standard deviation of maximum amount of heat release (J)

$$Q_{\max\_std} = \text{sqrt}((1 / (N-1)) \times \Sigma(Q_{\max} [N] - Q_{\max\_ave})^2) \quad \# \text{ sqrt: square root}$$

N : Number of cycles

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

Qmax\_ave : Averaged maximum amount of heat release (J) (calculated value)

**78. Qmax\_cov**

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

$$Q_{\max\_cov} = (Q_{\max\_std} / Q_{\max\_ave}) \times 100$$

Qmax\_std : Standard deviation of maximum amount of heat release (J) (calculated value)

Qmax\_ave : Averaged maximum amount of heat release (J) (calculated value)

### 79. Qab

Amount of heat release during the combustion period (J)

$$Q_{ab}[N] = Q_{\theta} [b, N]$$

Amount of heat release at point b at each cycle (sum from point a to point b at each cycle)

- N : Number of cycles  
Q $\theta$  : Amount of heat release (J) (calculated value)  
b : End point of combustion. Crank angle (CA) at which the value of dQ $\theta$  is changed to a negative value immediately after dQ $\theta$ max (calculated value)

### 80. Qab\_ave

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

$$Q_{ab\_ave} = (1 / N) \times Q_{ab} [N]$$

- N : Number of cycles  
Q $\theta$  : Amount of heat release during the combustion period (J) (calculated value)

### 81. RH $\theta$ [720,N]

Combustion mass rate (%)

$$RH_{\theta} [720, N] = Q_{\theta} [720, N] / Q_{ab}[N]$$

- N : Number of cycles  
Q $\theta$  : Amount of heat release (J) (calculated value)  
Q $\theta$  : The calculated sum (J) from point a to point b at each cycle

### 82. RH $\theta$ ave [720]

Average combustion mass rate (%)

$$RH_{\theta} \text{ ave}[720] = (1 / N) \times \Sigma(RH_{\theta} [720, N])$$

- N : Number of cycles  
RH $\theta$  : Combustion mass rate (%) (calculated value)

### 83. $\theta$ RH[N]

Crank angle at combustion mass rate N1 % (CA)

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

$$\theta RH[N] = \text{floor}(\text{round}(RH_{\theta}[720, N]), \text{ratio})$$

# floor: the angle whereby RH $\theta$  is greater than ratio (depending on the angular resolution)

# round: round to 1 digit after the decimal place

- N : Number of cycles  
RH $\theta$  : Combustion mass rate (%) (calculated value)  
ratio : Ratio for judging angle of combustion mass rate N1 % (%) (manually input)

**84.  $\theta_{RH\_ave}$** 

Averaged angle at combustion mass rate N1 % (CA)

$$\theta_{RH\_ave} = (1 / N) \times \Sigma(\theta_{RH} [N])$$

N : Number of cycles

$\theta_{RH}$  : Angle at combustion mass rate N1 % (CA) (calculated value)

**85.  $\theta_{RH\_std}$** 

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

$$\theta_{RH\_std} = \sqrt{(1 / (N - 1)) \times \Sigma(\theta_{RH} [N] - \theta_{RH\_ave})^2} \quad \# \text{ sqrt: square root}$$

N: Number of cycles

$\theta_{RH}$  : Angle at combustion mass rate N1 % (CA) (calculated value)

$\theta_{RH\_ave}$  : Averaged angle at combustion mass rate N1 % (CA) (calculated value)

**86.  $\theta_{RH\_cov}$** 

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

$$\theta_{RH\_cov} = (\theta_{RH\_std} / \theta_{RH\_ave}) \times 100$$

$\theta_{RH\_std}$  : Standard deviation of angle at combustion mass rate N1 % (CA) (calculated value)

$\theta_{RH\_ave}$  : Averaged angle at combustion mass rate N1 % (CA) (calculated value)

**87.  $\theta_{RH2}[N]$** 

Crank angle at combustion mass rate N2 % (CA)

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

$$\theta_{RH2}[N] = \text{floor}(\text{round}(RH\theta[720, N]), \text{ratio2})$$

*# floor: the angle whereby RH $\theta$  is greater than ratio2 (depending on the angular resolution)*

*# round: round to 1 digit after the decimal place*

N : Number of cycles

RH $\theta$  : Combustion mass rate (%) (calculated value)

ratio2 : Ratio for judging angle of combustion mass rate N2 % (%) (manually input)

**88.  $\theta_{RH2\_ave}$** 

Averaged angle at combustion mass rate N2 % (CA)

$$\theta_{RH2\_ave} = (1 / N) \times \Sigma(\theta_{RH2} [N])$$

N : Number of cycles

$\theta_{RH2}$  : Angle at combustion mass rate N2 % (CA) (calculated value)

**89.  $\theta_{RH2\_std}$** 

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

$$\theta_{RH2\_std} = \sqrt{(1 / (N - 1)) \times \Sigma(\theta_{RH2} [N] - \theta_{RH2\_ave})^2} \quad \# \text{ sqrt: square root}$$

N: Number of cycles

$\theta_{RH2}$  : Angle at combustion mass rate N2 % (CA) (calculated value)

$\theta_{RH2\_ave}$  : Averaged angle at combustion mass rate N2 % (CA) (calculated value)

### 90. $\theta_{RH2\_cov}$

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

$$\theta_{RH2\_cov} = (\theta_{RH2\_std} / \theta_{RH2\_ave}) \times 100$$

$\theta_{RH2\_std}$  : Standard deviation of angle at combustion mass rate N2 % (CA)  
(calculated value)

$\theta_{RH2\_ave}$  : Averaged angle at combustion mass rate N2 % (CA) (calculated value)

### 91. $\theta_{RH3}[N]$

Crank angle at combustion mass rate N3 % (CA)

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

$$\theta_{RH3}[N] = \text{floor}(\text{round}(RH\theta[720, N]), \text{ratio3})$$

*# floor: the angle whereby RH $\theta$  is greater than ratio3 (depending on the angular resolution)*

*# round: round to 1 digit after the decimal place*

N : Number of cycles

RH $\theta$  : Combustion mass rate (%) (calculated value)

ratio3 : Ratio for judging angle of combustion mass rate N3 % (%) (manually input)

### 92. $\theta_{RH3\_ave}$

Averaged angle at combustion mass rate N3 % (CA)

$$\theta_{RH3\_ave} = (1 / N) \times \Sigma(\theta_{RH3} [N])$$

N : Number of cycles

$\theta_{RH3}$  : Angle at combustion mass rate N3 % (CA) (calculated value)

### 93. $\theta_{RH3\_std}$

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

$$\theta_{RH3\_std} = \text{sqrt}((1 / (N - 1)) \times \Sigma(\theta_{RH3} [N] - \theta_{RH3\_ave})^2) \quad \# \text{ sqrt: square root}$$

N: Number of cycles

$\theta_{RH3}$  : Angle at combustion mass rate N3 % (CA) (calculated value)

$\theta_{RH3\_ave}$  : Averaged angle at combustion mass rate N3 % (CA) (calculated value)

### 94. $\theta_{RH3\_cov}$

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

$$\theta_{RH3\_cov} = (\theta_{RH3\_std} / \theta_{RH3\_ave}) \times 100$$

$\theta_{RH3\_std}$  : Standard deviation of angle at combustion mass rate N3 % (CA)  
(calculated value)

$\theta_{RH3\_ave}$  : Averaged angle at combustion mass rate N3 % (CA) (calculated value)

### 95. $PoIY\theta [720]$

Polytropic index

$$PoIY\theta [720] = -(\log_{10}(P\theta \text{ ave}[n-1] / P\theta \text{ ave} [n]) / \log_{10} (V\theta [n-1] / V\theta [n]))$$

$n = 0$  to 719. when  $n = 0$ ,  $PoIY\theta = 1$ .

$P\theta \text{ ave}$  : Average cylinder pressure (kPa)

$V\theta$  : Piston displacement ( $m^3$ )

**96. Vmax**

Maximum piston displacement ( $\text{m}^3$ )

When **Clearance volume** is selected on the Parameter Settings screen

$$V_{\text{max}} = V_{\text{st}} + V_{\text{c}}$$

When **Compression ratio** is selected on the Parameter Settings screen

$$V_{\text{max}} = V_{\text{st}} + (V_{\text{st}} / (\text{Cr} - 1))$$

Vst :           Piston displacement ( $\text{m}^3$ )  
 Vc :           Clearance volume ( $\text{m}^3$ )  
 Cr :           Compression ratio (manually input)

**97. chX $\theta$  ave[720]**

Other signals (crank angle graph data)

$$\text{chX}\theta \text{ ave}[720] = (1 / N) \times \Sigma(\text{chX}[720, N])$$

N :           Number of cycles  
 chX :       Measured value of chX

**95. chXave[N]**

Other signals (cycle graph data)

$$\text{chXave}[N] = \text{ave}(\text{chX}[720, N]) \quad \# \text{ ave: average value}$$

N :           Number of cycles  
 chX :       Measured value of chX

**99. a\_ave**

Average start point of combustion (CA)

$$a_{\text{ave}} = (1 / N) \times \Sigma a[N]$$

N :           Number of cycles  
 a :           Crank angle (CA) at which the value of  $dQ\theta$  is changed to a positive value immediately before  $dQ_{\text{max}}$  (calculated value)  
 When manually input, the setting value is assumed to be point "a."

**100. b\_ave**

Average end point of combustion (CA)

$$b_{\text{ave}} = (1 / N) \times \Sigma b[N]$$

N :           Number of cycles  
 b :           Crank angle (CA) at which the value of  $dQ\theta$  is changed to a negative value immediately after  $dQ_{\text{max}}$  (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	Maximum amount of heat release and the corresponding crank angle
	Combustion mass rate	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) Estart point of combustion (point b)

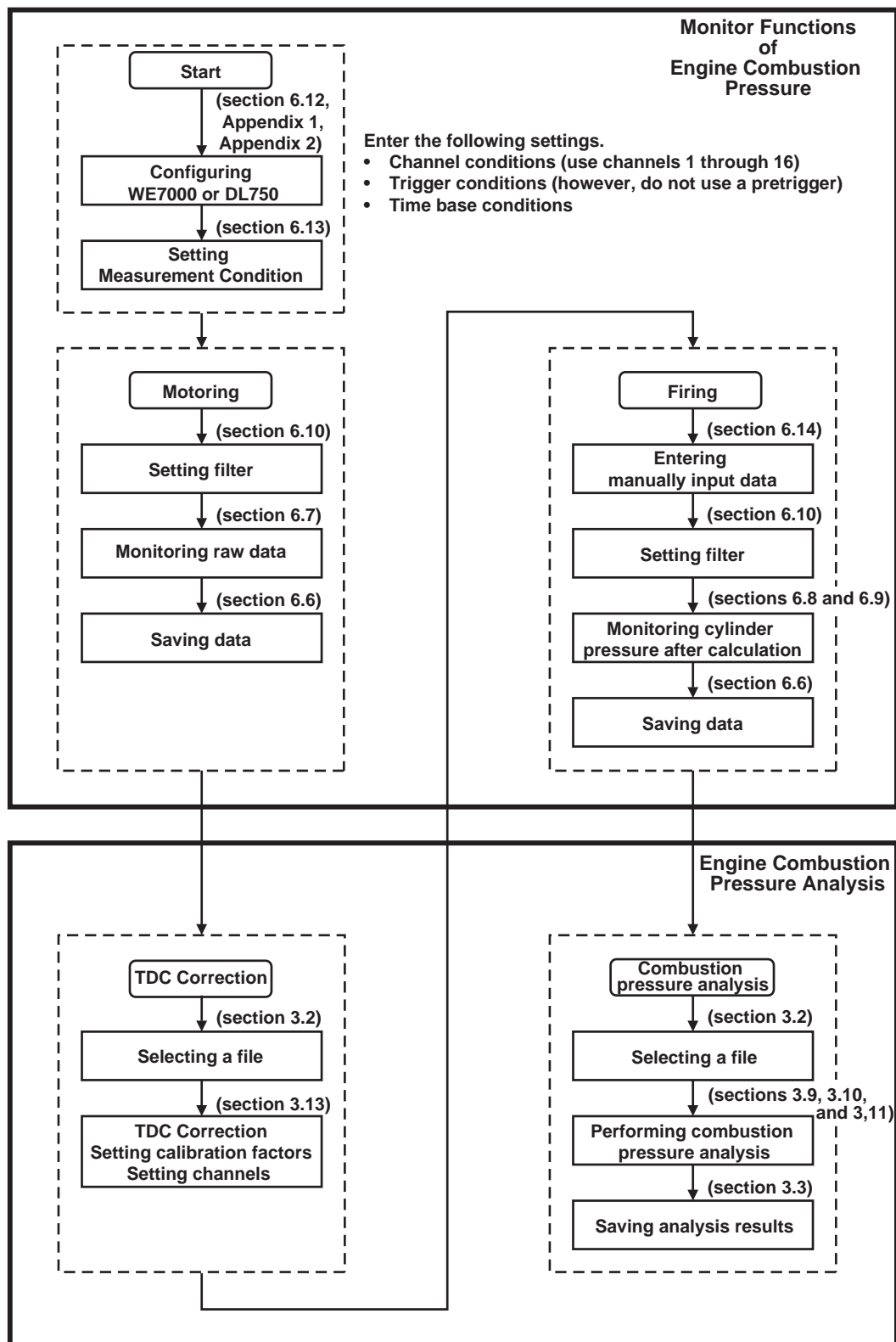
- If filters were applied, the filtered waveforms are displayed.
- The specified number of cycles of data to undergo combustion pressure analysis is acquired, then saved in WVF format.
- **Entering Conditions**

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.

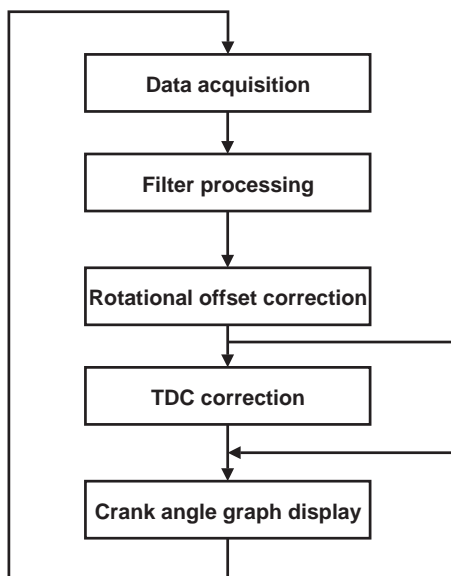




## Processing

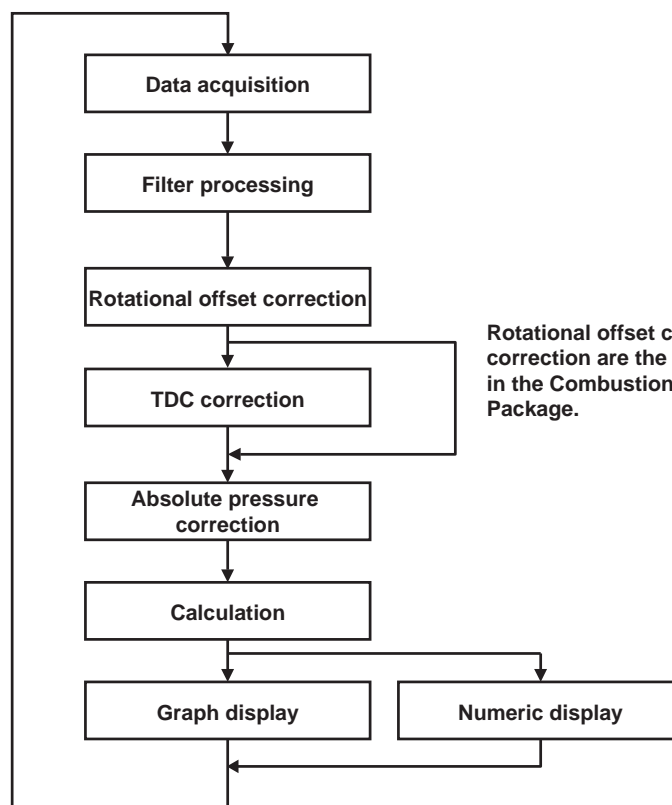
The monitor function operates as shown in the figure below.

### <Motoring Mode>



Rotational offset correction and TDC correction are the same process as in the Combustion Pressure Analysis Package.

### <Firing Mode>



Rotational offset correction and TDC correction are the same process as in the Combustion Pressure Analysis Package.

---

## 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.

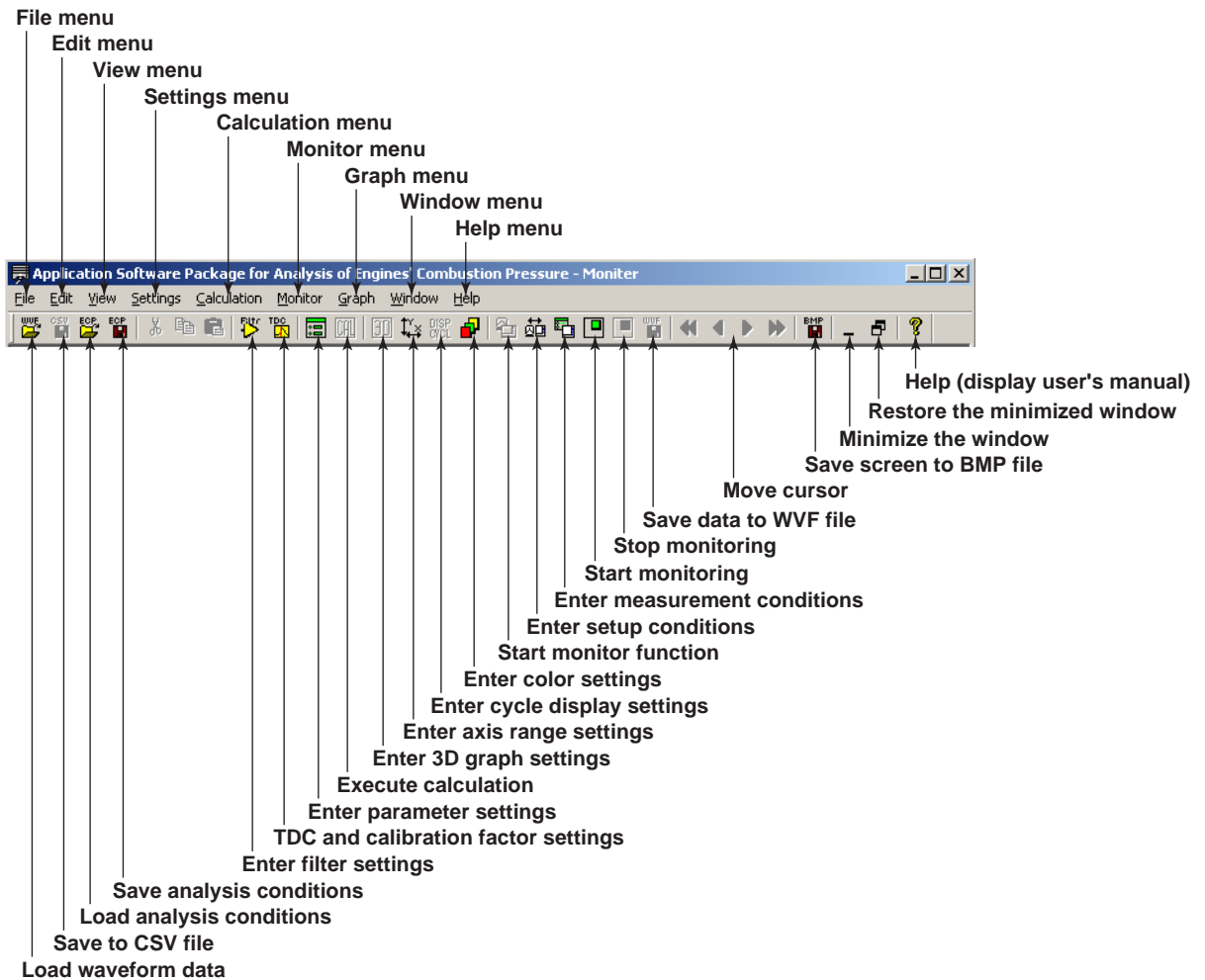
### Hardware Configuration

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.

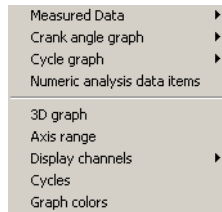
**Menu Bar of the Monitor for the Engine Combustion Pressure Analysis Package**



## 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.

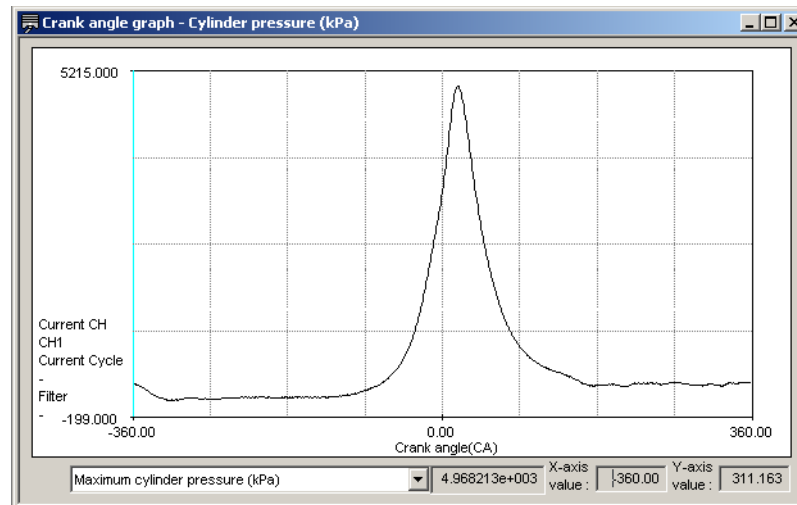
---

## 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

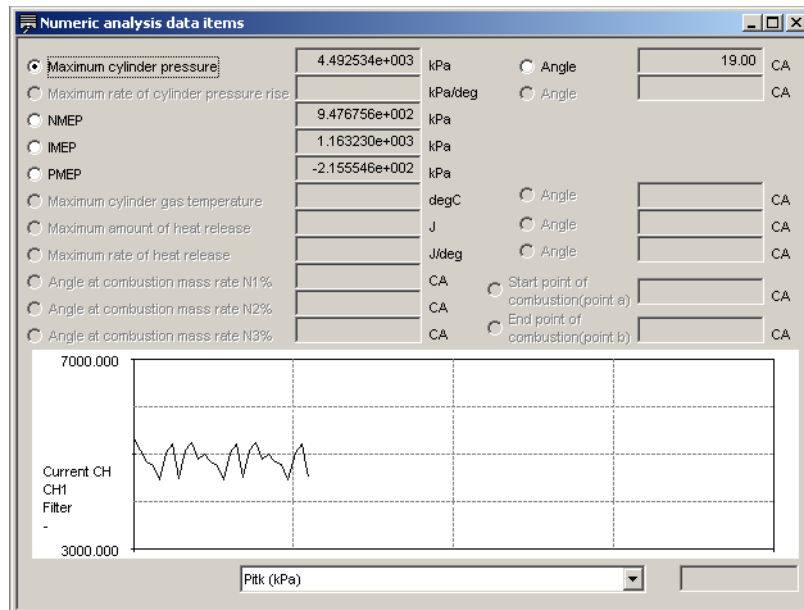


### Functions

- 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.

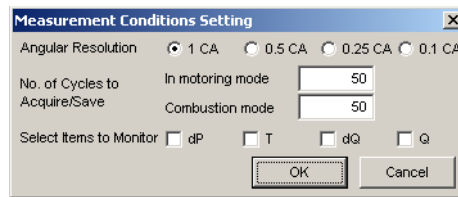
---

## 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) Estart point of combustion (point b)

### Setting/Display Data

No.	Item	Initial Value	Data Type	Size	Numeric Data		Input (I) / Select (S)
					Min. Value	Max. Value	
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

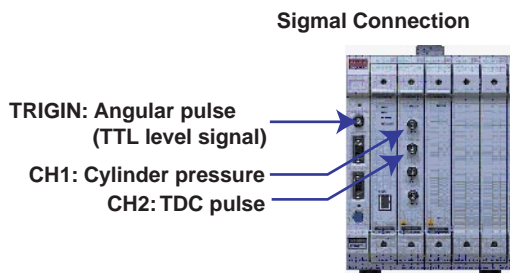
The messages in the table below appear in response to errors that may occur.

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

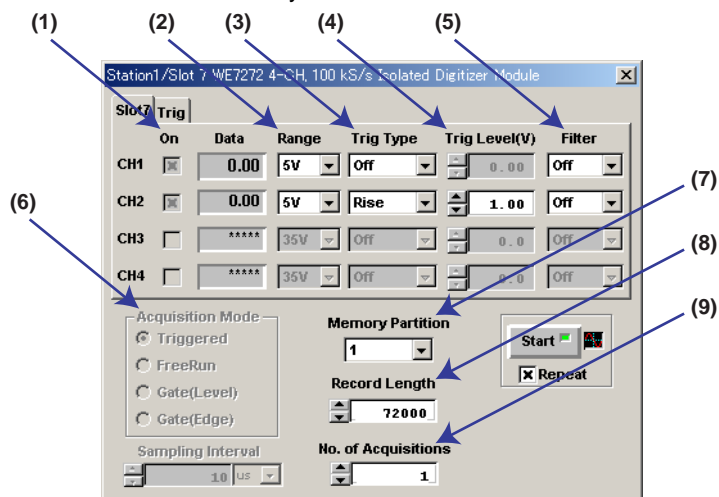
First, enter all necessary settings on the WE7000 control software.

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.

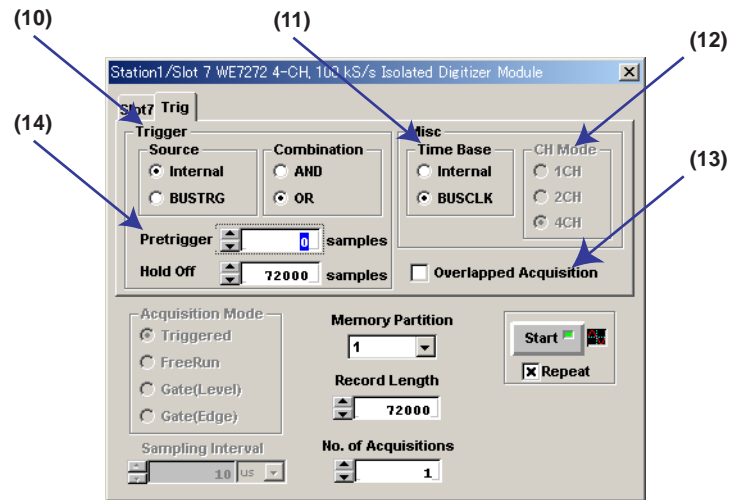


<Module Settings>

- (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  $\geq (\text{no. of analyzed cycles} + 3) \times 1 \text{ cycle data length}$   
For 4-cycle engine: 1 cycle data length =  $(360/\text{res}) \times 2$   
For 2-cycle engines: 1 cycle data length =  $(360/\text{res})$   
 $\text{res} = \text{angular resolution (1, 0.5, 0.25, 0.1)}$   
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 =  $(100+3) \times 1440 = 148320$ , 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.



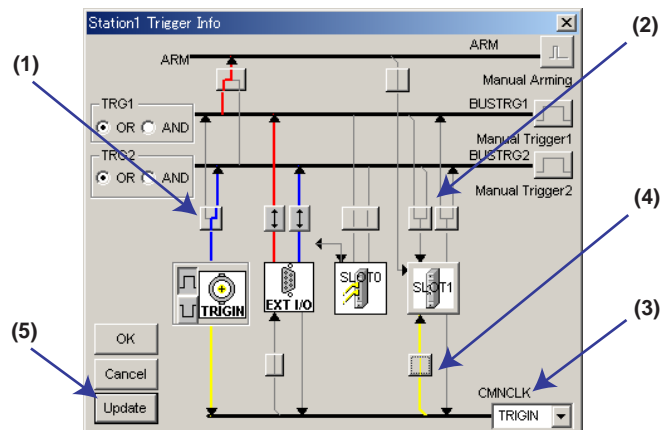
- (10) **Trigger/Source**  
Select **Internal**.
- (11) **Misc/Time Base**  
Select **BUSCLK**.
- (12) **CH Mode**  
Select the number of measurement channels depending on the number of input channels.
- (13) **Overlapped Acquisition**  
Unselected
- (14) **Pretrigger**  
Set to **0**.



<Trigger Information Settings>

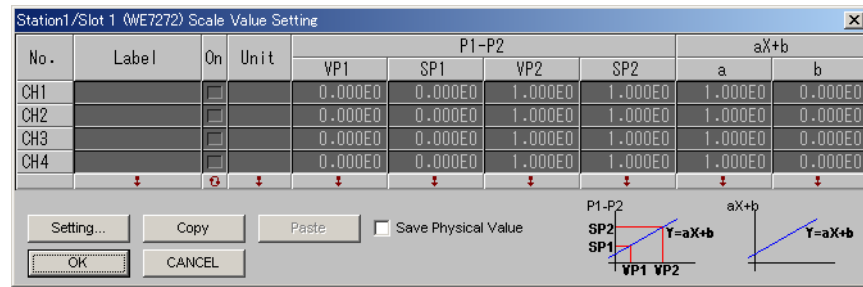
Enter the following settings for the TDC pulse trigger signal and the angular pulse sampling signal.

- (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.



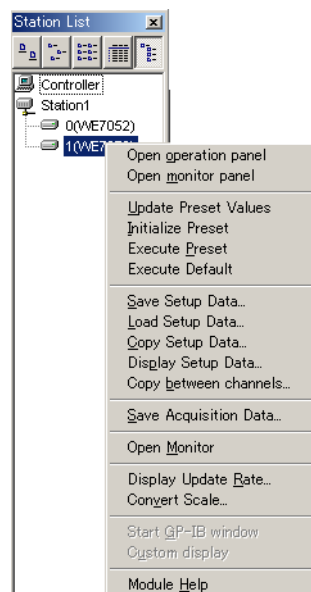
### <Scaling Information Settings>

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.

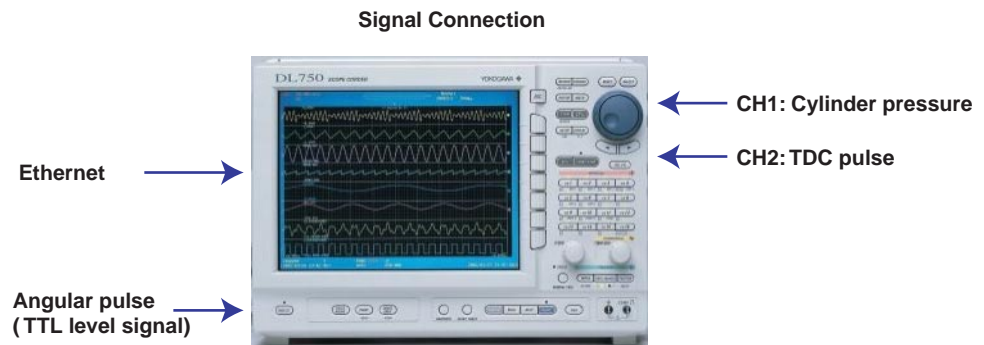


### <Exiting the Control software>

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

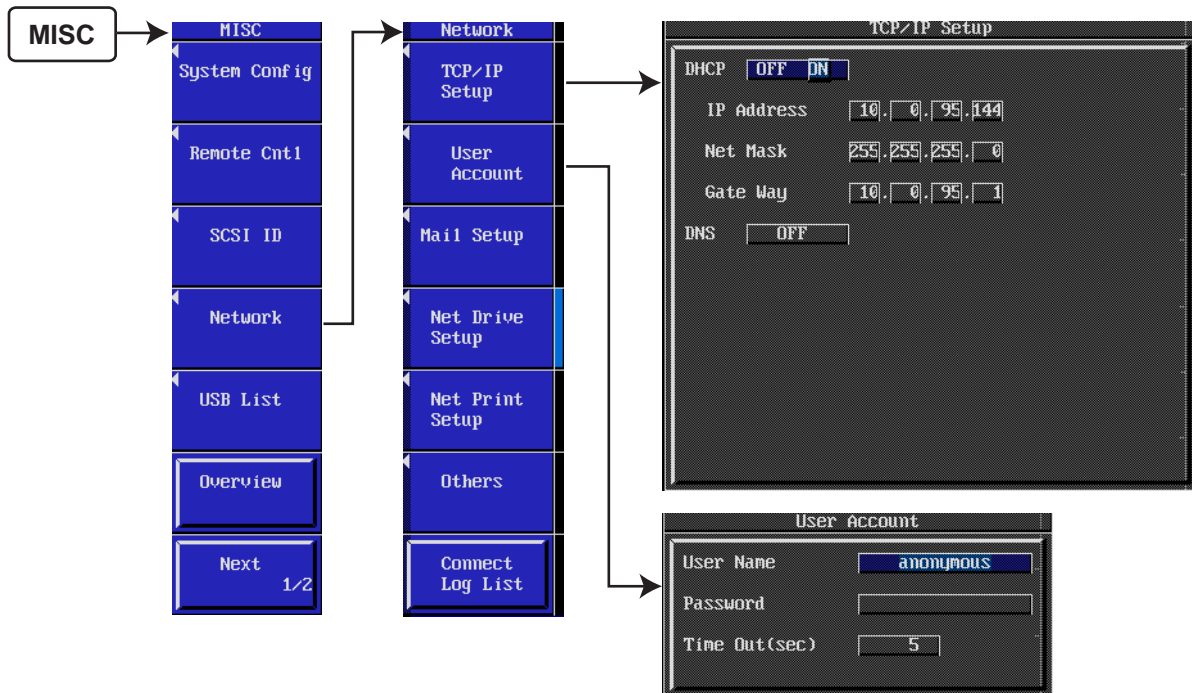
First, enter all necessary settings on the DL750. The following is an example of how the DL750 would be configured to measure the pressure in one cylinder with one 701251 measurement module.



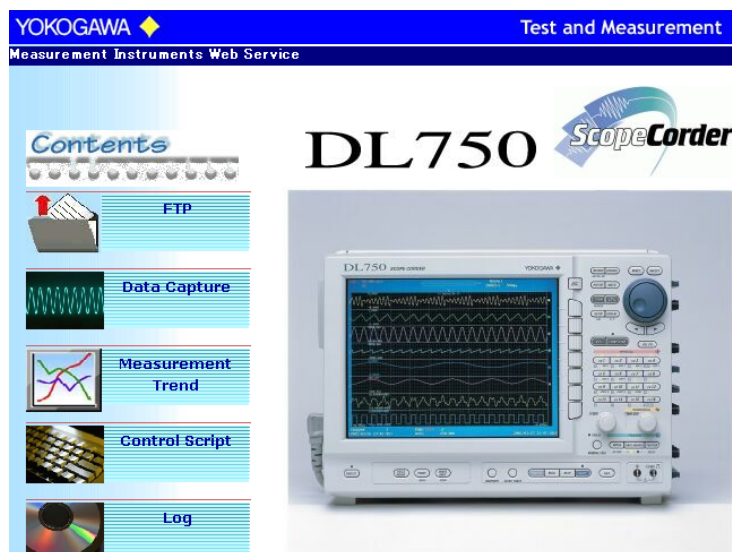
Connect an Ethernet cable to the main unit and turn on the power.

#### <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.

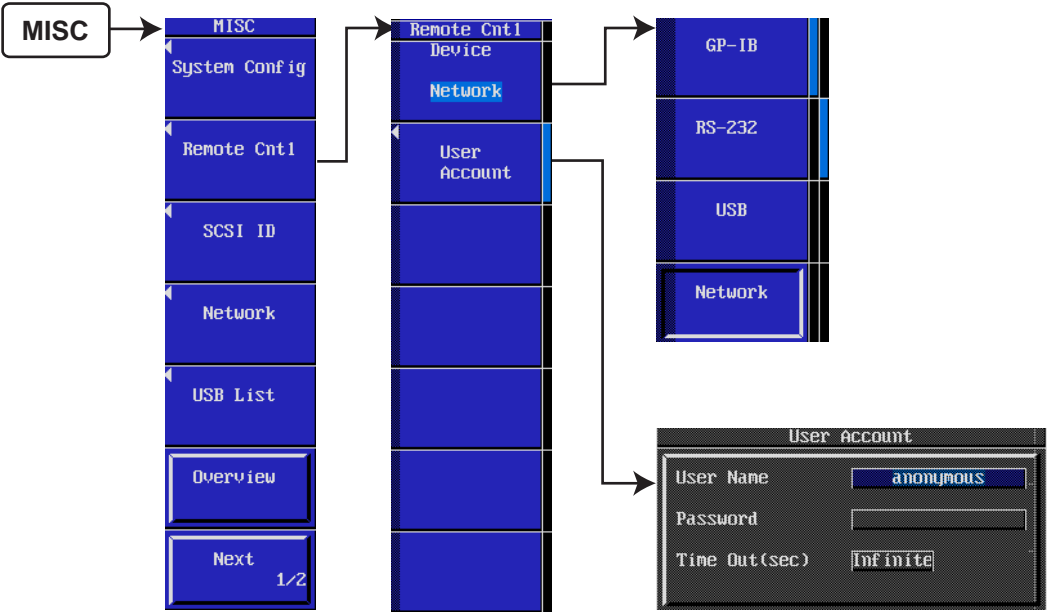


The setup procedure is explained in the DL750 user's manual. Also, you must enter the network information and user account information that you set here in the Monitor Function add-on for the Engine Combustion Pressure Analysis (see section 6.2). After entering the above settings, enter the DL750 IP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



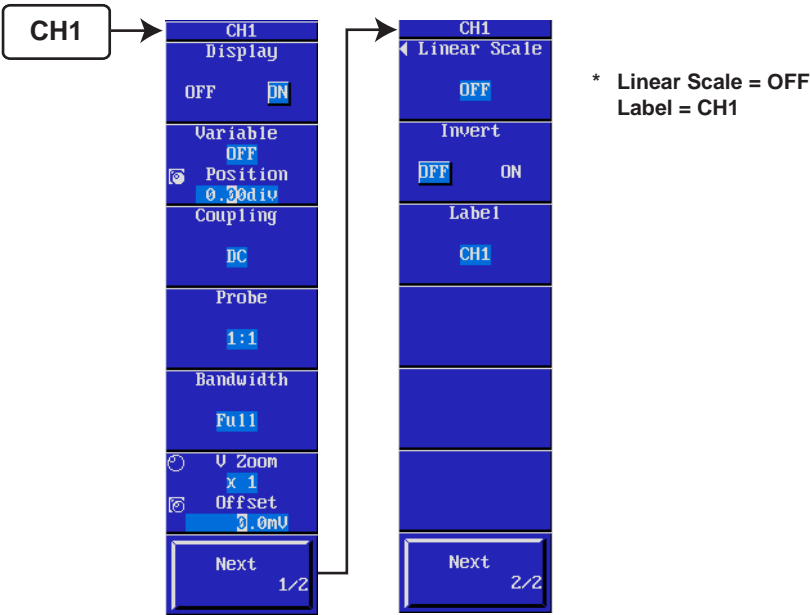


<Remote Control Settings>  
Set so that remote control is available through the network.



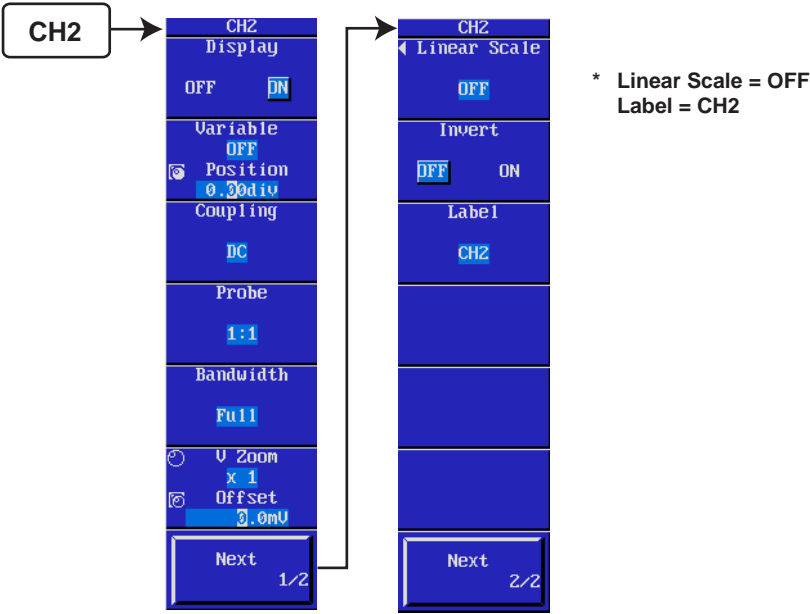
<CH1 (Cylinder Pressure Signals) Settings>

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



<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:



### <Trigger Mode Settings>

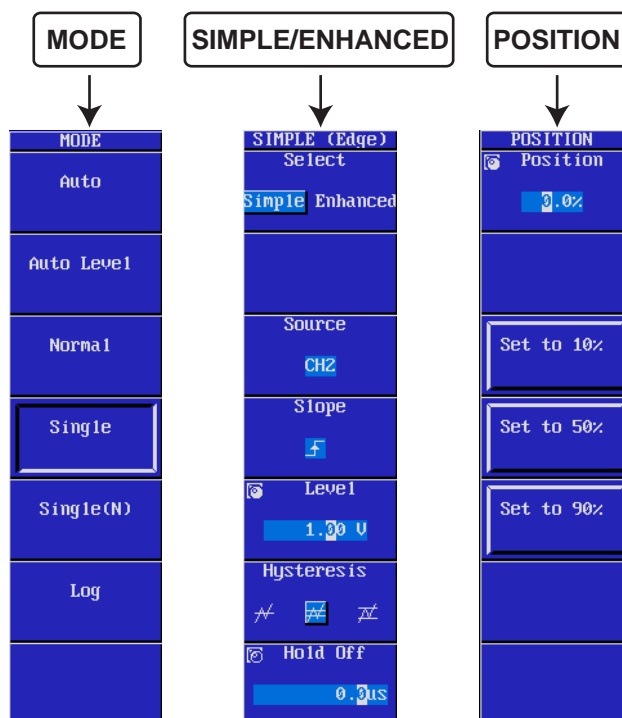
Press the **MODE** key to set the trigger mode to **Single**. This is automatically set with the Monitor Function add-on for the Engine Combustion Pressure Analysis.

### <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  $\geq$  (no. of analyzed cycles + 3)  $\times$  1 cycle data length

For 4-cycle engine: 1 cycle data length =  $(360/\text{res}) \times 2$

For 2-cycle engines: 1 cycle data length =  $(360/\text{res})$

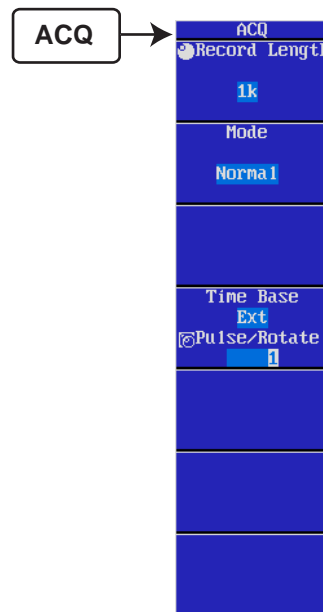
*res* = angular resolution (1, 0.5, 0.25, 0.1)

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 =  $(100+3) \times 1440 = 148320$ , 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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