Engine Combustion Pressure Analysis Package

FOR DL700, DL750 & WE7000

New feature: Analyze and display multiple data simultaneously
Yokogawa is pleased to introduce version 4.00 which accomplished the further evolution

- Various types of engine analysis included as standard
- Analyze and display multiple data simultaneously NEW
- Analysis of waveform data from the DL750, DL708E/DL716, and WE7000
  - Support for transient operations as well as normal operations
  - USB 1.1 added for real-time monitor interface of DL750 NEW
- Gasoline, natural gas, and diesel versions available
- Saving and recalling of analysis conditions NEW
  - Saving of analysis results in CSV format
  - Support for 2-cycle and 4-cycle engines
- Support for 0.1° crank angle resolution (select 0.1, 0.25, 0.5, or 1.0)
- Support for both all-cycle-average and cycle-by-cycle absolute pressure correction methods
- Greater scope of analysis (LNV, misfire rate, and cylinder-to-cylinder average value) NEW

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**Turn Your General-Purpose Measuring Instrument into an Engine Combustion Pressure Analysis System**

This software package lets you turn general-purpose measuring instruments used primarily in field experiments into an engine combustion pressure analysis system.

The Engine Combustion Pressure Analysis Package enables engine combustion pressure to be analyzed using measurement data from the WE7000 as well as the DL750 and other Yokogawa DL700 series instruments, which are widely used throughout the auto industry. The package also allows you to monitor analysis data during measurement by connecting your DL750 or WE7000 to a PC through an Ethernet connection or through USB 1.1 (only for DL750). Now that these general-purpose measuring instruments can be used for engine combustion pressure analysis, setting up engine data analysis equipment is much easier.

**Analyze and display multiple data simultaneously**

Multiple analysis data can be checked simultaneously while performing online monitoring and analysis.

**Greater scope of analysis**

The number of arbitrary setting points for combustion mass rate has been increased from one to three. In addition, LNV, misfire rate and cylinder-to-cylinder average value can now also be analyzed.

**Transient combustion pressure analysis**

Analysis of transient combustion pressure is possible thanks to the addition of intake pipe pressure, intake pipe temperature, engine rpm, and fuel consumption as measurement items. This type of analysis is invaluable for developing clean, high-efficiency engines for which there is strong demand.

### Configuration of Engine Combustion Pressure Analysis System

**EXT-CLK signal**
- Crank angle pulse
  - 1.0 CA
  - 0.5 CA
  - 0.25 CA
  - 0.1 CA

**Trigger signal**
- TDC signal

**Sensor signal**
- Cylinder internal pressure (maximum 8 cylinders)
- Intake pipe pressure
- Other signals

**Recommended module for each measuring instrument**

<table>
<thead>
<tr>
<th>Maximum number of cylinders</th>
<th>Recommended module (card)</th>
<th>Real-time monitoring capability</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL708E 6</td>
<td>701853 (100 kS/s, 16-bit, 1 channel)</td>
<td>No</td>
</tr>
<tr>
<td>DL716 8</td>
<td>701853 (100 kS/s, 16-bit, 1 channel)</td>
<td>No</td>
</tr>
<tr>
<td>DL750 8</td>
<td>701251 (1 MS/s, 16-bit, 2 channels)</td>
<td>Yes</td>
</tr>
<tr>
<td>WE7000 8</td>
<td>707272 (100 kS/s, 16-bit, 4 channel)</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>707275 (1 MS/s, 14-bit, 4 channel)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*1 Reference measurement ranges for each sampling rate:
- 100 kS/s: 0.5 CA—approximately 8000 rpm
- 1 MS/s: 0.1 CA—approximately 16,000 rpm

**Actual vehicle operation**
- Normal operation
- 4-cycle/2-cycle
- Gasoline/diesel/LPG, LNG

**Engine Combustion Pressure Analysis Package**
- **Real-Time Monitor**
  - P-V graph
  - Numerical analysis

**CSV files**
- Numerical analysis
- Crank angle graph
- Cycle graph
- All-cycle crank angle graph

**PC System Requirements**
- CPU: Pentium III, 1 GHz or higher
- Memory: 128 MB or more
- Hard disk: 256 MB or more
- USB, Ethernet

*NEW*
Specifications

Engine Combustion Pressure Analysis Package

(1) Analysis procedure

1. Motoring
   - No fuel injection/no firing
   - Measure cylinder internal pressure by motoring
     - WVF file
   - Calculate TDC correction angle
   - Set physical conversion coefficient
   - Set crank angle range in absolute pressure correction interval
     - Interval for correcting TDC correction value conversion coefficient
   - Analyze
   - Save CSV file

2. Firing
   - With fuel injection/with firing
   - Measure cylinder internal pressure by firing
     - WVF file
   - Set manually input parameters

(2) Supported engine types
   - Gasoline/diesel/natural gas, and 2-cycle/4-cycle

(3) Measurement channels
   - Maximum 16 channels (analog signals)
   - • Cylinder internal pressure: Maximum 6 channels
   - • Other signals: Maximum 15 channels

(4) Maximum number of analyzed cycles
   - User-defined intervals (up to 800 cycles) in the following valid cycle data are extracted and analyzed.
     - At 1.0 CA: 25,000 cycles
     - At 0.5 CA: 12,500 cycles
     - At 0.25 CA: 6250 cycles
     - At 0.1 CA: 2500 cycles

(5) Angle resolution:
   - 1.0/0.5/0.25/0.1 CA

(6) Conversion to physical values
   - Physical value = A × Voltage value + B

(7) Filter processes
   - Filter types: None, low-pass, band-pass, high-pass
   - Characteristics: 4th Order (24 dB/oct) Butterworth
   - Cutoff frequencies
     - At 1.0 CA: Rpms 7.2-order (times) (2%) to 72th order (times) (20%)
     - At 0.5 CA: Rpms 14.4-order (times) (2%) to 144th order (times) (20%)
     - At 0.25 CA: Rpms 28.8-order (times) (2%) to 288th order (times) (20%)
     - At 0.1 CA: Rpms 72th order (times) (2%) to 720th order (times) (20%)

(8) Rotation error correction
   - If the cylinder internal pressure peak is less than –180 C or greater than +180 CA, then a rotation error is recognized and a shift of 360 CA is made.

(9) TDC correction
   - The cylinder internal pressure data on the first channel (first firing) during motoring are averaged over all cycles. The maximum value in the data is detected, and this value, together with the ten points on both sides (21 points in total), are approximated in a second-order equation to determine the maximum value. The corresponding angle position (in increments of 0.01) is used as the Top Dead Center (TDC). Or, the TDC position may be set by manual input.

(10) Absolute pressure correction
   - The measured cylinder internal pressure is converted to absolute pressure.

(11) Crank angle graph display for measurement data
   - • Motoring and firing displays
   - • Displays before and after TDC correction
   - • Display for each channel and all-channel overlapping display
   - • Display for each cycle, display for cycle average, and all-cycle overlapping display
   - • Direct reading of values using cursor

(12) Analysis
   - • Parameters for all engine types (gasoline, natural gas, and diesel)
   - • Parameters for natural gas engines
   - • Parameters for diesel engines

The measured cylinder internal pressure is converted to absolute pressure.

Con rod length, bore diameter, piston offset, stroke length, gap volume or gap volume, compression ratio, absolute pressure correction method, number of data points for determining start/end of explosion, fuel consumption, atmospheric temperature, atmospheric pressure, engine rpms, supercharging pressure, Starting angle of correction interval, Ending angle of correction interval, Search range of maximum rate of heat release, Ratio for judging angle of combustion mass rate (3 locations), Value for judging misfire

• Parameters for gasoline engines
  - Gas constant, intake volume efficiency, fuel specific gravity, specific heat ratio
  - Engine output, number of engine cylinders, methane composition ratio, ethane composition ratio, propane composition ratio, isobutane composition ratio, normal butane composition ratio, residual oxygen concentration in exhaust gas, lower calorific value of gas fuel

• Parameters for diesel engines
  - Gas constant, intake volume efficiency, fuel specific gravity, exhaust pressure, exhaust gas temperature, supercharger entrance temperature, boost temperature, supercharger entrance pressure, piston head ratio, cylinder wall temperature, cylinder head wall temperature, piston head wall temperature, lower calorific value

Rotation error: Yes (peaks at exhaust and intake strokes)
Rotation error: No (peaks at compression and explosion strokes)
(12-2) Numerical results
- Results for all engine types (gasoline, natural gas, and diesel)
  - 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 PIMEP of all cycles and cylinders, Minimum NIMEP of all cycles and cylinders, LN'V of NIMEP of all cycles and cylinders, Minimum IMEP of all cycles and cylinders, LN'V of IMEP of all cycles and cylinders
  - Averaged values, standard deviations, and fluctuation rates for the following:
    - Cylinder internal pressure maximum value
    - Pressure rise rate maximum value, output mean effective pressure, indicated mean effective pressure, pump mean effective pressure, cylinder internal gas temperature maximum value, heat release rate maximum value, heat release amount maximum value, fuel consumption ratio
    - Average combustion start position (point a), average combustion end position (point b)
  - Results for natural gas engines
    - Required oxygen amount, exhaust gas amount, theoretical air amount, theoretical exhaust gas amount, produced water amount, theoretical dry exhaust gas amount, air excess rate, intake air amount, intake amount (fuel + air), volume efficiency, fuel gas specific gravity, intake air weight, intake fuel weight, intake exhaust gas weight, mixed gas constant, gas fuel lower calorific value, cooling loss, cooling loss rate, net heat efficiency, friction loss, combustion efficiency, isochoric degree, indicated efficiency
  - Results for diesel engines
    - Intake fuel weight, intake air weight, air excess rate, corrected gas constant, residual gas weight

(12-3) Crank angle graph
- Cylinder internal pressure, pressure rise rate, heat release amount, heat release rate, heat release rate (heat obtained from gas combustion) (diesel only), heat release rate (heat loss) (diesel only), combustion mass ratio, cylinder internal gas temperature, polytropic index, specific heat ratio (excluding gasoline), other signals, graph of cylinder internal pressure versus stroke volume, graph of logarithmic cylinder internal pressure versus logarithmic stroke volume

(12-4) Cycle Graph
- Crank angle at maximum cylinder pressure, Crank angle at maximum rate of cylinder pressure rise, Crank angle at maximum rate of heat release, Crank angle at combustion mass rate N % (3 points), NIMEP, IMEP, PIMEP, Averaged maximum cylinder pressure of all cylinders, Averaged crank angle at maximum cylinder pressure of all cylinders, Averaged maximum rate of cylinder pressure rise of all cylinders, Averaged angle at maximum rate of cylinder pressure rise of all cylinders, Averaged angle at maximum rate of cylinder pressure rise of all cylinders, Averaged NMEP of all cylinders, Averaged IMEP of all cylinders, Averaged PIMEP of all cylinders, Crank angle at maximum rate of heat release, Other signals

(12-5) Graph features
- Display for each channel and all-channel overlapping display
- Display for each cycle, display for cycle average, and all-cycle overlapping display (when crank angle graph is displayed)
- Direct reading of values using cursor
- Automatic/manual scale settings for X and Y axes

(12-6) Analysis results file saving (CSV format)
- Comments
  - Measurement data saving date, data name, tester, department, test name, engine model, serial number, test location, test bench type, comments
  - Manual input fields
  - TDC correction value, physical value conversion coefficients (A, B), crank angle range for absolute pressure correction, channel names, and manual input fields during analysis
  - Numerical results data
  - Numerical results during analysis
  - Crank angle graph data (cycle average values)
    - Crank angle graph data during analysis and measurement data used in analysis
    - Cycle graph data
    - Cycle graph data during analysis and measurement data used in analysis
    - Crank angle graph data for specified cycle range
    - During analysis: Cylinder internal pressure, cylinder internal pressure rise rate, cylinder internal gas temperature, heat release rate, heat release amount, combustion mass ratio
  - Measurement data used in analysis

(12-7) 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

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**Engine Combustion Pressure Analysis Package Real-time Monitor**

(1) Flow chart

1. Start measurement
2. Collect measurements for 3 cycles
3. Correct rotation error
4. Correct TDC
5. End measurement
6. Correct absolute pressure
7. Calculations
8. Crank angle graph
9. Numerical results

(2) Numerical results for all engine types (gasoline, natural gas, and diesel)
- Crank angle at combustion mass rate N % (3 points) Cylinder internal pressure maximum value and crank angle, pressure rise rate maximum value and crank angle, output mean effective pressure, indicated mean effective pressure, pump mean effective pressure, heat release amount maximum value and crank angle, heat release rate maximum value and crank angle, combustion mass ratio
- Crank angle graph
- Cycle graph for all engine types (gasoline, natural gas, and diesel)
- Numerical results for all engine types (gasoline, natural gas, and diesel)
- Cycle graph for all engine types (gasoline, natural gas, and diesel)

(3) Crank angle graph for all engine types (gasoline, natural gas, and diesel)
- Cylinder internal pressure, pressure rise rate, heat release amount, heat release rate, combustion mass ratio, cylinder internal gas temperature, polytropic index, specific heat ratio
- Other signals
- Graph of cylinder internal pressure versus stroke volume

(4) Graph features
- Display for each channel and all-channel overlapping display
- Direct reading of values using cursor
- Automatic/manual scale settings for X and Y axes

(5) File saving
- (5-1) Collection conditions
  - An amount of data, calculated from the angle resolution (1.0/0.5/0.25/0.1 CA) and the number of saving cycles (up to 800 cycles), is collected continuously, with the TDC signal serving as a trigger.
- (5-2) File format
  - WVF format (binary files conforming to Yokogawa's standard)

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**Product list**

<table>
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<tr>
<th>Product</th>
<th>Model</th>
</tr>
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<tbody>
<tr>
<td>Engine Combustion Pressure Analysis Package</td>
<td>707764</td>
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<tr>
<td>- Gasoline engine version</td>
<td>707765</td>
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<tr>
<td>- Natural gas engine version</td>
<td>707766</td>
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<td>Engine Combustion Pressure Analysis Package Real-time Monitor (*)</td>
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<td>- Gasoline engine version</td>
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<td>- Natural gas engine version</td>
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<tr>
<td>- Diesel engine version</td>
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**NOTICE**

- Before operating the product, read the instruction manual thoroughly for proper and safe operation.
- If this product is used with a system requiring safeguards that directly involve personnel safety, please contact the Yokogawa sales offices.