ENGINE TEST SET UP

2 CYLINDR, 4 STROKE, DIESEL

Product Code
238

Instruction manual

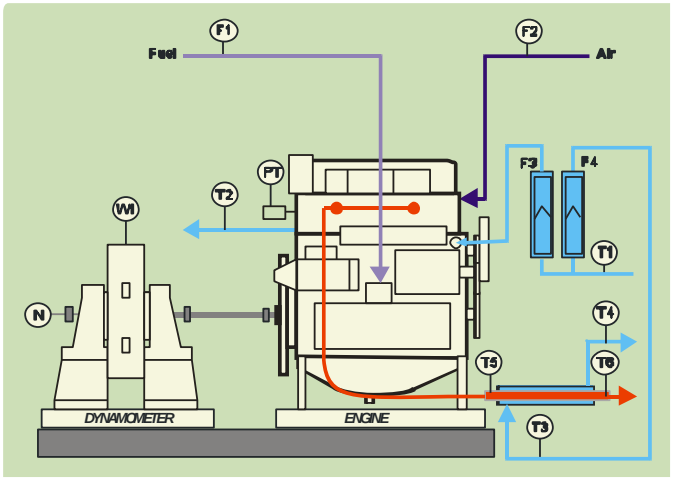
Contents

APEX INNOVATIONS

Description

The setup consists of twocylinder, four stroke, Diesel engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ–PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The set up has stand-alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator, load indicator and engine indicator. Rotameters are provided for cooling water and calorimeter water flow measurement.

The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Labview based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation.



Schematic arrangement
(Performance evaluation)

Specifications

Product	Engine test setup 2 cylinder, 4 stroke, Diesel (Computerized)
Product code	238
Engine	Make Mahindra, Model Maxximo, Type 2 Cylinder, 4 Stroke, Diesel CRDI with ECU, water cooled, Power 18.4Kw at 3600 rpm, Torque 55 NM at 2500rpm,stroke83 mm, bore 84mm, 909 cc,CR 18.5
Dynamometer	Type eddy current, water cooled, with loading unit
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer (Orifice dia 35 mm)
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Make-Apex, Model AX-409.
Digital milivoltmeter	Range 0-200mV, panel mounted
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, Range 0–1200 Deg C, Output 4–20 mA
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"Enginesoft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type self priming
Overall dimensions	W 2000 x D 2750 x H 1750 mm

Shipping details

Gross volume 2.74m^3, Gross weight 855kg, Net weight 695kg

Installation requirements

Electric supply

Provide 230 +/- 10 VAC, 50 Hz, single phase electric supply with proper earthing. (Neutral – Earth voltage less than 5 VAC) Separate UPS for computer.

5A three pin socket with switch (2 Nos.) 15A three pin socket with switch (1 No)

Water supply

Continuous, clean and soft water supply@ 2000 LPH, at 10 m. head. Provide tap with 1" BSP size connection

Computer

Typical configuration as follows:

Computer with OS Windows 8 or higher, RAM Min 4 GB, DVD drive, high speed USB port, Monitor with pixel setting 1200x900,

Space

3500Lx4000Wx2000H in mm (Refer foundation drawings)

Drain

Provide suitable drain arrangement (Drain PVC pipe 75 mm 2.5" size)

Exhaust

Provide suitable exhaust arrangement (Exhaust GI/MS pipe 32 NB/1.25" size)

Foundation

Refer the document "Site Utilities" under Solutions tab on our websitewww.apexinnovations.co.in

Fuel, oil

Diesel@10 lit.

Oil @ 3.5 lit. (20W40)

Packing slip

Total boxes: 10, Volume: 2.74 m^3, Gross weight: 855 kg. Net wt. 694 kg

Box No.1/10	Engine Set up Assembly Size W1700xD800xH1200 mm; Volume:1.63m3	Gross weight: 475kg Net weight: 475kg
1	Engine test setup assembly Engine + Dynamometer + Base frame	1 No.
Box No.2/10	Engine panel box Size W990xD475xH500 mm; Volume:0.24m^3	Gross weight: 78kg Net weight: 50kg
1	Engine panel box assembly Transmitter panel, Fuel pipe, Fuel DP transmitter, Air transmitter, NI USB 6210, power supply and wiring, Manometer with PU tube.	1 No.
Box No.3/10	Engine panel box structure Size W800xD475xH500 mm; Volume:0.19m^3	Gross weight: 56kg Net weight: 31kg
1	Engine panel box structure assembly Rotameters with piping (2) Dynamometer loading unit clamp (1)	1 No.
Box No.4/10	Calorimeter Size W650xD275xH325 mm; Volume:0.06m^3	Gross weight: 45kg Net weight: 22kg
1	Calorimeter assembly	1 No.
Box No.5/10	Exhaust pipe Size W1100xD750xH325 mm; Volume:0.27m^3	Gross weight: 40kg Net weight: 26kg
1	Exhaust pipe	1 No.
Box No.6/10	Pump Size W300xD225xH300 mm; Volume:0.02m^3	Gross weight: 14kg Net weight: 7kg
1	Pump	1 No.
Box No.7/10	Battery Size W150xD225xH250 mm; Volume:0.01m^3	Gross weight: 25kg Net weight: 17kg
1	Battery	1 No.
Box No.8/10	Dash board panel Size W500xD400xH300 mm; Volume:0.06m^3	Gross weight: 32kg Net weight: 20kg
1	Dash board panel with support structure	1 No.
2	Fuel throttle body with cable	1 No.

Box No.9/10	Engine wiring Size W500xD400xH300 mm; Volume:0.06m^3	Gross weight: 30kg Net weight: 12kg
1	Piezo powering unit	1 No.
2	Load indicator	1 No.
3	Digital voltmeter	1 No.
4	Dynamometer loading unit	1 No.
5	Pressure gauge	1 No.
6	Wiring set	1 No.
7	Load cell with nut bolt	1 No.
8	Crank angle sensor	1 No.
9	Temperature sensor	5 Nos.
10	Piezo sensor	1No/2Nos.
11	Piezo adaptor	1 No.
12	Low noise cable	1No/2Nos.
13	Data acquisition device and driver CD	1 No.
14	Apex Enginesoft DVD CD	1 No.
15	Set of loose nut bolts	1 No.
16	Tool kit	1 No.
17	Fuel caps(2), Teflon tape(2) & Gasket shellac(1)	1 No.
18	Set of instruction manuals consisting of: Instruction manual CD (Apex) DP transmitter Dynamometer Calibration sheets for load cell and Piezo sensor	1 No.
Box No.10/10	Engine piping Size W1250xD450xH350mm; Volume: 0.20m^3	Gross weight: 60kg Net weight: 25kg
1	Piping set (14 pieces) Engine water inlet and outlet, Dynamometer water inlet and outlet, Calorimeter water inlet and outlet, Air hose pipe, Pump suction connection with strainer, Pump outlet, Engine water inlet and outlet hose, Water supply hose pipe, Drain pipe (3 components)	1 No.

2	Water supply pipe 1” hose	1 No.
3	Load cell bracket	1 set
4	Fuel measuring unit 2Nos (one spare)	1 No.
5	Wiring channel set	1 No.
6	Engine air connection pipe	1 No.
7	Fuel filter assembly	1 No.
8	Exhaust extension pipe with socket and bend	1 No.
9	Pump bracket	1 No.
10	Air box connection	1 No.
11	Calorimeter exhaust outlet flange	1 No.

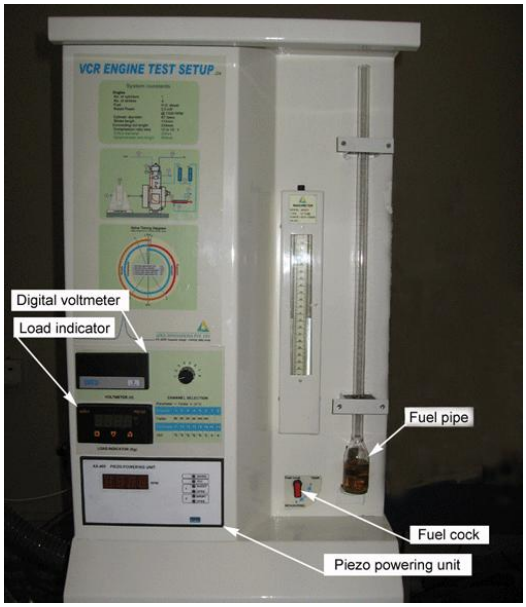
Installation

- Unpack the box(es) received and ensure that all material is received as per packing slip. In case of short supply or breakage contact Apex Innovations / your supplier for further actions.
- Remove the packings, paper boxes, wrappers from the components.
- Refer the various photographs below and note locations of different components.
- Install *Engine setup assembly* on the foundation and tighten the foundation bolts. Note that *Crank angle sensor*, and *Load cell* are fitted on the dynamometer and *Piezo sensor* is fitted on the engine. The dynamometer body is clamped with its base by locking flat which is to be removed. There are jack bolts below the dynamometer which are raised upwards to restrict the swiveling motion. These bolts to be lowered to allow free motion of the body of the dynamometer.
- Keep *Engine panel box structure* near *Engine setup assembly*. Two rotameters are fitted in the panel box structure. Inside the rotameters plastic rods are inserted to arrest the movement of respective floats. These rods are to be removed. Note the C type clamp provided for clamping the dynamometer loading unit.
- Collect the *Calorimeter* and *Calorimeter structure* from Calorimeter box. Remove calorimeter from the structure, reverse the structure and put it near engine. Fit calorimeter over the structure.

- Collect the Engine Panel Box. It is fitted with Manometer, Fuel DP transmitter, Air transmitter, Orifice for air metering, Transmitter panel(fitted with Power supply

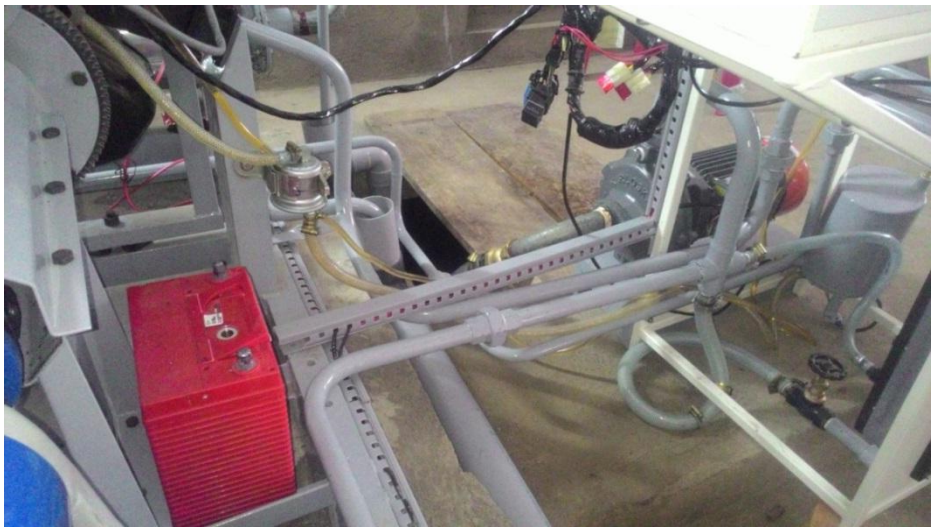
and five Temperature transmitters), NI-6210 USB interface with cable for computer.

- Check all terminal connections, component mounting and wiring screws
- Fit the Engine panel box assembly on the Panel box structure with four bolts.

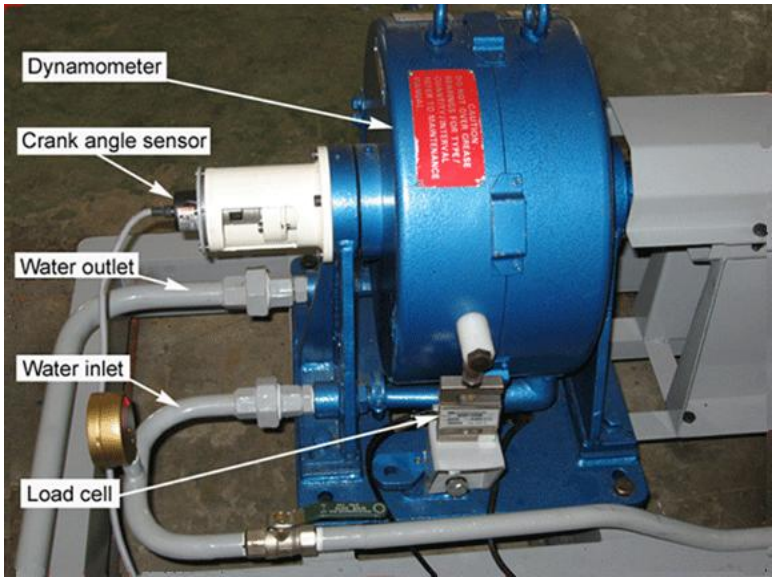


- Collect *Piezo powering unit* (Ax409), *Dynamometer loading unit* (AX155), *Load indicator*, *and Digital voltmeter* (SMP35) from "Engine wiring" box.
- Remove the covers of Piezo powering unit and Dynamometer loading unit and confirm that all components inside are at proper location and tightly fitted. Remove any packing material inside dynamometer loading unit. Confirm smooth working of loading knob on its front. The cover of the dynamometer loading unit is to be fitted after inserting the unit in the Engine panel support structure
- Fit the Piezo powering unit (AX409) and put its clamps. Connect Electric supply cables and a 9 pin connector at Output
- Fit load indicator (SV8 series) and put its clamps. Connect 6 wires at respective terminals.
- Fit Voltmeter (Meco) and put its clamps. Connect 4 wires at the back terminals.
- Fit Dynamometer loading unit in the Engine panel structure after removing C clamp. Fit its cover and then fit the C clamp.

- Remove the Exhaust pipe packed in wooden box placed inside "Engine piping" box and connect it between calorimeter exhaust inlet and engine exhaust outlet.
- Connect Exhaust extension pipe at the outlet of calorimeter. Insert additional pipe in between and take the exhaust out of the room. At the end put Exhaust muffler.
- Remove Pump packed in wooden box placed inside "Engine piping". Fit Pump bracket to the Engine panel structure and fit pump on it.

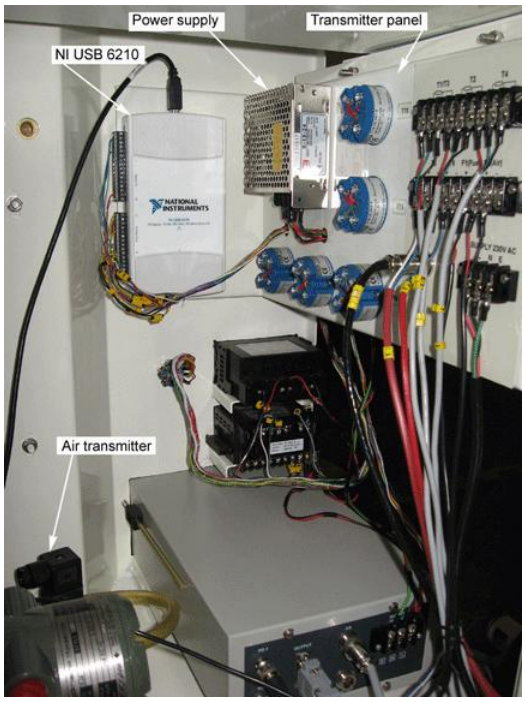


- Collect the piping pieces form "Engine piping box". Clean the pipes internally to remove any dust and particles. Complete the piping as follows:
    - Assemble the PVC drain pipes (3 components) as per the marking done. Put it between Engine panel and Engine set up assembly.
    - Connect *Engine water inlet* from engine cooling rotameter to water inlet on engine body. Separate *Engine water inlet hose pipe* with clamps is provided for connecting the engine side end of the pipe.
    - Connect *Engine water outlet*. Connect *Engine water outlet hose* between the outlet pipe and engine body. The Outlet pipe is to bolted on the base frame and the water outlet drains in drain pipe.
    - Fit *Pump outlet* at the delivery side of the pump. Connect Rotameter inlet hose pipes to the pump outlet.
    - Connect *Dynamometer water inlet* from Pump inlet to dynamometer.
    - Connect *Dynamometer water outlet* from dynamometer to drain pipe.
    - Connect *Calorimeter inlet* from rotameter to calorimeter.
    - Connect *Calorimeter water outlet* to drain.
    - Fit *Strainer and hose nipple* at the pump inlet and connect Water supply hose pipe. Connect this hose pipe to site water supply.
    - Fit *Air box connection* to air box and connect *Air hose pipe* from air box to engine.
    - The fuel pipe is put on engine and its one end is connected to fuel filter. Connect the other end in the engine panel at the brass hose tee in the fuel line. The fuel line is to be routed through the wiring channels.



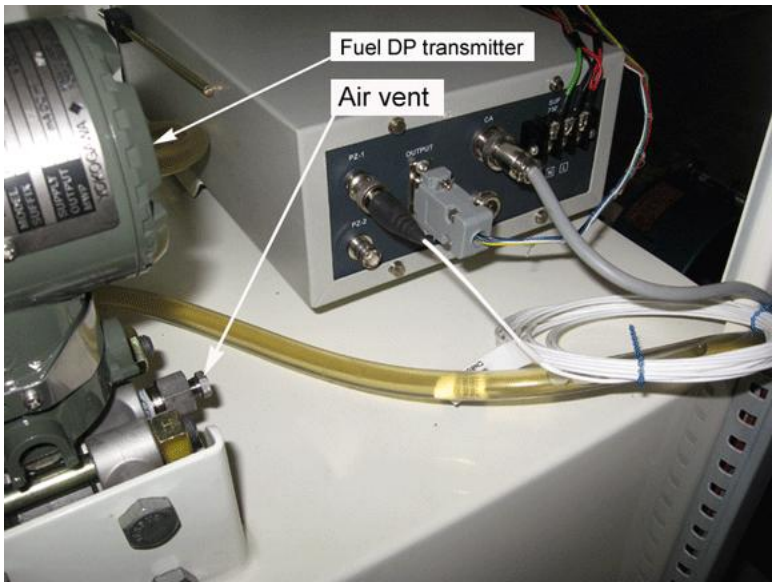
- Fit *Pressure gauge* on dynamometer inlet pipe.
- Fit wiring *PVC channel set*.
- Collect the wiring set from *Sensors* bag and fit 5 temp sensors at respective places. (i) RTD T1/T3 at the inlet water at pump outlet. (ii) RTD T2 at the Engine outlet water on the engine head. (iii) RTD T4 at the calorimeter water outlet. (iv) Thermocouple T5 at the Exhaust inlet of calorimeter and (v) Thermocouple T6 at the exhaust outlet of calorimeter. Route the wiring from PVC wiring channels.

- Collect *Electric supply cable* packed in packing (named as *Sensors)* and connect L N E terminals to the transmitter panel at supply 230V. Connect its 3 pin (F) connector to Dynamometer loading unit at Supply. Connect male 3 pin connector to Electric supply available at the site. Route the cable through wiring channel.
- Connect cable from Crank angle sensor, 4 pin round (F), to CA of Piezo powering unit.
- Connect cable from Load cell, 4 pin round (F), to Load on transmitter panel.
- Remove black cap on piezo sensor and connect piezo cable to the sensor. Connect other end of the piezo cable to Piezo powering unit at PZ1.
- Connect dynamometer supply cable, 3 pin (M), to Output VDC of dynamometer loading unit.
- Take out USB cable from NI USB 6210 from Engine Panel and connect to Computer. The cable is short in length. A spare cable of extra length is also supplied.


Power supply
Transmitter panel
NI USB 6210
Air transmitter

Commissioning

- Remove oil cap fitted on the on the top of the engine and fill lubrication oil (SAE20W40 or equivalent). About4.5lit oil is needed.To reach most of the oil to oil sump, it is necessary to wait for about 5 minutes, after filling the oil. Check the oil level by the dip stick provided in the crank case.
- Two fuel tanks are provided on the top portion of the engine panel. Fill Diesel in one of the fuel tanks or both tanks. Use Fuel funnel for filling. Put fuel caps on the fuel tanks.
- Open the Fuel cock at the outlet of the fuel tank in which Diesel is filled. Note the Fuel in the glass fuel pipe. Remove complete air from the fuel pipe between Engine panel and Engine setup.
- **Air removal from fuel DP:** Remove air bubbles from the fuel line connecting to Fuel DP transmitter. For removing the air loosen the Air vent on the fuel DP transmitter and allow some fuel to come out from it and then tighten it gently.



- Fill water in the manometer up to "0" mark level.
- Ensure that Jack bolts under dynamometer are lowered for free movement of the dynamometer body.
- Switch on electric supply of the panel box and ensure that Piezo powering unit, load indicator and voltmeter are ON.
- **TDC adjustment:**
    - Rotate the geared flywheel slowly in anticlockwise direction (Viewed from dynamometer end) till the CA mark on the geared flywheel matches with the reference pointer provided on the engine body. This rotation movement should be unidirectional.

  - Check if the TDC light on the Piezo powering unit is lit. If not adjust the crank angle sensor as follows:
  - Loosen the four screws on the flange provided for clamping the crank angle sensor on the mounting bracket.
  - Ensure that crank angle sensor body is free to rotate about its axis. Rotate the sensor body slowly till the TDC light on the piezo powering unit glows. Ensure that the flywheel is adjusted for CA mark as explained above.
  - Clamp the four screws on the flange.

- By using multipoint selector switch on the engine panel confirm that all voltage values are properly displayed. Convert the voltage values in to respective temperature reading using parameter chart pasted on the panel. The values displayed should show around ambient temperatures.
- Confirm the load value on the load indicator is zero. Rotate the dynamometer body so that the nylon bush is pressing the load cell. Ensure that the load values on the load indicator are changing.
- **Engine starting:**
  - Ensure that all foundation bolts, propeller shaft bolts are properly tightened.
- Keep water circulation on, Set @ 400 lph and 250 lph flow rates for engine cooling and calorimeter respectively.
- Start the engine and allow it to run for 5 minutes in idling condition. Confirm that engine speed is displayed on Piezo powering unit.
- Rotate the knob on dynamometer loading unit and gradually load the engine. Ensure that the load on the load indicator gradually increases.
- Gradually increase throttle to full open condition and load the engine (by knob on DLU) simultaneously maintaining engine speed at @ 2000-3000 RPM. Check load & RPM reading on the indicator. Load the engine up to 10-15 kg allow it to run for 5 minutes.
- Ensure that voltages displayed for all 5 temperature sensors are logically correct.
- Stop the engine after releasing the load.
- Switch off the pump.
- For software installation on the computer proceed to Software section

Precautions

- Use clean and filtered water; any suspended particle may clog the piping.

- Circulate dynamometer and engine cooling water for some time after shutting down the engine.
- Piezo Sensor Handling:
    - While engine is running ensure cooling water circulation for combustion pressure sensor / engine jacket.
    - Diaphragm of the sensor is delicate part. Avoid scratches or hammering.
    - A long sleeve is provided inside the hole drilled for piezo sensor. This sleeve is protecting the surface of the diaphragm. While removing the sensor, this sleeve may come out with the sensor and fall down or loose during handling.

Status of the sensor is indicated on the Piezo powering unit. Damages to the electronic parts of the sensor or loose connection are indicated as "open" or "Short" status on Piezo powering unit.

Software

COMPUTER REQUIREMENT

Typical configuration as follows:

Computer with OS Windows 8 or higher, RAM Min 4 GB, DVD drive, high speed USB port, Monitor with pixel setting 1200x900,

Refer ICEngineSoft DVD supplied with the setup. Follow the instructions and instal the software.

For instructions related to software refer help provided in the software.

Troubleshooting

Note: For component specific problems refer components' manual

Problems	Possible causes / remedies
Engine does not start	• Switch on electric supply to the engine panel, pump • Insufficient fuel • Air trapped in fuel line • Engine EARTH cable • Low Battery voltage: Recharge battery • Engine preloaded: Switch off dynamometer loading unit or adjust load to minimum
Dynamometer does not load the engine	• Faulty wiring • No DC voltage at the outlet of dynamometer loading unit
Faulty air flow	• Air hose leakage at connections with air-box and with engine.
Faulty fuel flow	• Improper closing of fuel cock. • Air trap in pressure signal line to fuel transmitter
Software does not work	• Faulty or wrong USB port • Virus in computer • Loose connections
Faulty indicated power	• TDC setting disturbed. Readjust TDC setting. • Improper configuration data
Faulty pressure crank angle diagram	• Improper earthing • Wrong reference pressure setting in configuration file. Adjust the value such that suction stroke pressure just matches the zero line. • If peak pressure is not at the TDC, TDC setting disturbed, readjust • If peak pressure shifts randomly with respect to TDC, coupling of crank angle sensor may be loose
Faulty speed indication	• Broken coupling of crank angle sensor
Incorrect temperature	• Check the connection between thermocouple and temperature indicator/transmitter. Note that yellow

indication	cable of thermocouple is positive and red is negative. • Open or damaged temperature sensor
Improper load indication	• Excessively raised jack bolts of the dynamometer.

Experiments

1 Study of engine performance (Computerized mode)

OBJECT

To study the performance of 2 cylinder, 4 stroke, CRDI Diesel engine connected to dynamometer in computerized mode.

PROCEDURE

- Ensure that all the nut bolts of engine, dynamometer, propeller shaft, base frame are properly tightened.
- Ensure that sufficient lubrication oil is present in the engine sump tank. This can be checked by marking on the level stick
- Ensure sufficient fuel in fuel tank. Remove air in fuel line, if any.
- Switch on electric supply and ensure that PPU (Piezo powering unitAX-409), DLU (Dynamometer loading unitAX-155), Load indicator and Voltmeter are switched on.
- Start Computer and open "ICEngineSoft" (Double click "ICEngineSoft" icon on the desktop) Select:File| Configure |Product
- In "Configure the product" windowselect "Load Default".
- Under "Select File" choose your Setup from drop down menu
- Under "Set Parameters" study the parameters under Engine, Sensors, **Combustion and Performance** tabs. Click on "OK "
- **Changing the parameters:**
- If any parameter is to be changed Click "New/Change". Change the parameter under respective tabs. After all changes click "Save & Apply". Click "OK" to save changes.
- Click "OK" again to reconfigure changes.
- **Reconfiguring the graphs**
- Select:File| Configure |Graph.Under "Configure The Graphs" window "Select a Configuration" from the drop down menu.
- Study the preset configuration of X axis, Y axis, graph ranges, for the selected graphs. Click "CLOSE & SET". Configure the necessary parameters, ranges, as required. Click "SAVE" and then "Close & SET"

- Note three vertical tabs viz. Combustion, Performance, Report. Under vertical Combustion tab horizontally following tabs are available: Combustion, Cylinder Pr., PV, Log PV, RPR etc. Similarly under other vertical tabs we get more horizontal tabs. Start water pump. Adjust the flow rate of "Rotameter (Engine)" to 300-400 LPH and "Rotameter (Calorimeter)" to 200-250 LPH by manipulating respective globe valves provided at the rotameter inlet. Ensure that water is flowing through dynamometer at a pressure of @ 1 to 2 Kg/cm2.(For Hydraulic dynamometer at a pressure of @ 1.5 to 2 Kg/cm2)
- Keep the dynamometer loading knob at minimum position.Change the Fuel cock position from "Measuring" to "Tank". Start the engine by starter keys switch and allow it to run at idling condition for 4-5 minutes.

Online Data acquisition

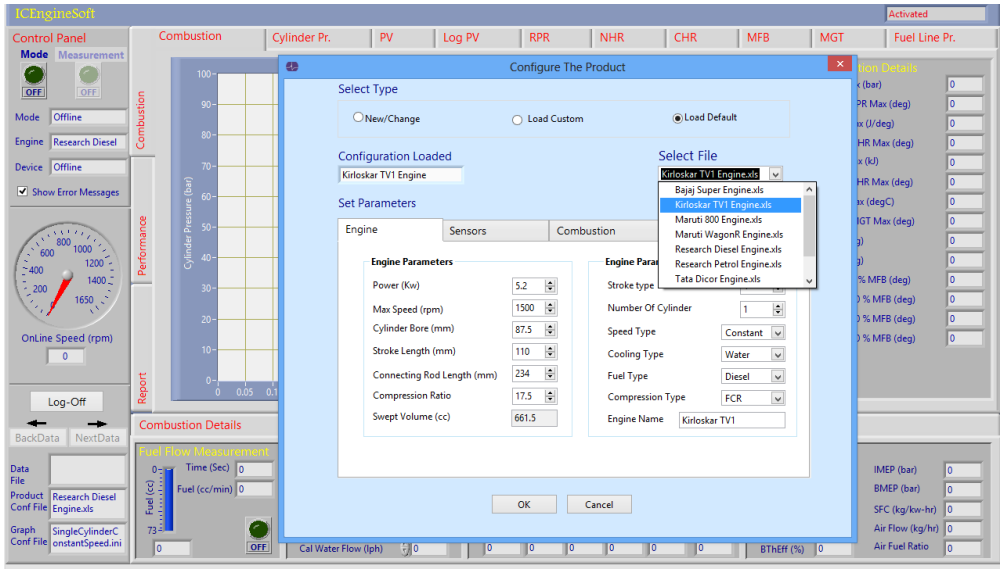
- Click toggle switch **"Mode"**to Start/Stop the device communication. (Green color indicates ON condition) Click toggle switch **"Measurement"** to Start/ Stop data acquisition. (Green color indicates ON condition)
- Ensure that Speed, Temperatures and Manometer reading are correctly displayed on the PC. These readings should tally with those displayed on the engine panel.
- Gradually increase throttle to full open condition and load the engine (by DLU knob) simultaneously maintaining engine speed at @ 2000-2500 RPM. Check load & RPM reading on the indicator and computer are same.
- Wait for steady state (for @ 3 minutes) and ensure that RPM & Load is constant during this period. Change the Fuel cock position from "Tank" to "Measuring". Click "Log on" on. The fuel metering is ON for next 60 seconds. During first 30 seconds enter engine water flow, calorimeter jacket cooling water flow in LPH. Click "OK" after recording fuel reading. Enter the file name under which the records to be stored. The first reading data is now saved. Change the Fuel cock position from "Measuring" to "Tank".
- Gradually decrease the load to the increase speed in steps of @500 RPM up to @ 3500 rpm maximum and repeat the data logging for each observation.
- After finishing all the readings simultaneously decrease the load on the engine by dynamometer loading knob at unload position.Gradually decrease throttle to full down condition.
- Click toggle switch **"Measurement"** to Stop data acquisition on PC (Green color indicates off condition). Click toggle switch **"Mode"** to Stop the device communication

- **Click: File|Data|Close.**Stop the engine by pressing engine stop starter keys. Allow the water to circulate for about 5 minutes for engine cooling and then Stop the pump.
- **Click: File|Data|Open**. on PC, Select the File under which the readings are stored and click "OK". To view next readings click "Next Data". The results are displayed on all the three screens
- For printing the results click "Print" and select appropriate option.
- Click "File Close" after printing & checking. Click "Exit" and then Shut Down the computer.

CONFIGURATION DATA

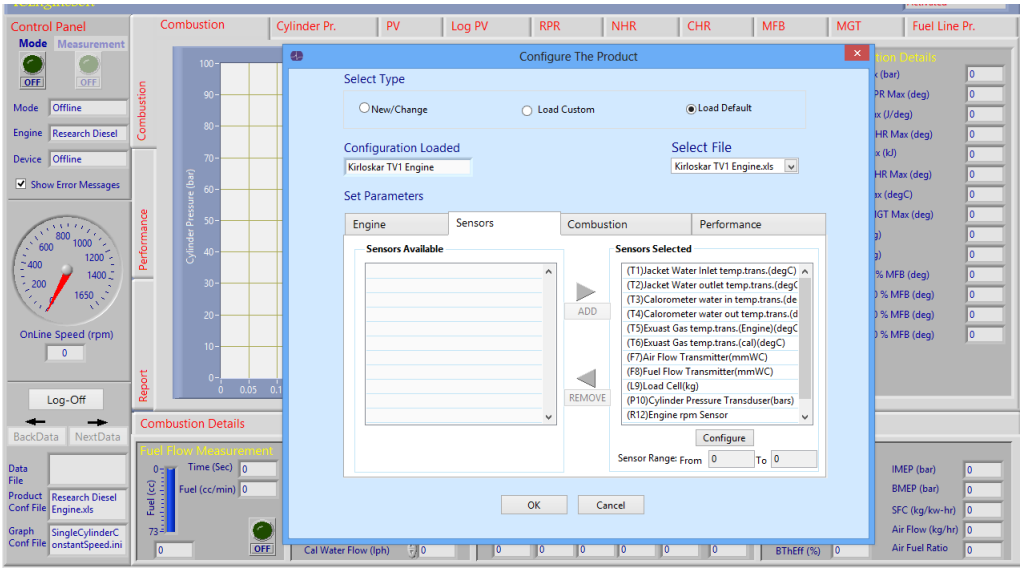
Set Parameters (Default values)
Engine
Engine parameters

Power (KW): **18.4**	Stroke type: 4
Max Speed (rpm): **3600**	Number of Cylinder: **2**
Cylinder Bore (mm): 83	Speed Type: Variable
Stroke Length (mm):84	Cooling Type: Water
Connecting Rod Length (mm): 141	Fuel Type: Diesel
Compression Ratio: 18.5	Compression Type: FCR
Swept Volume (cc): 909	Engine Name: MahindraMaxximo



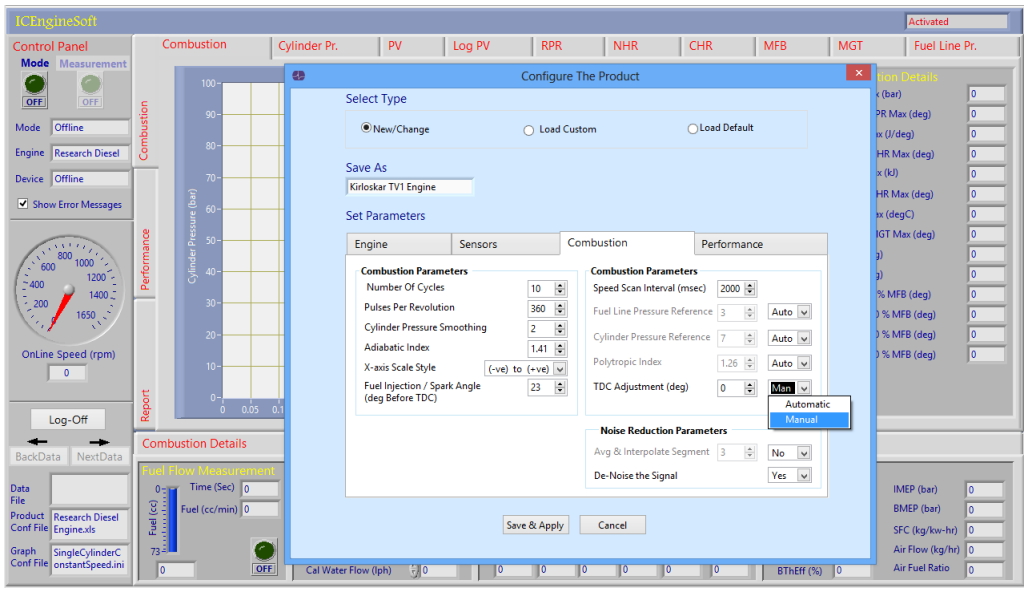
Sensors

Sensors Available	Sensors Selected
(P11) Diesel Pressure Transducer (bars)	(T1) Jacket Water Inlet temp. trans. (degC)
	(T2) Jacket Water outlet temp. trans. (degC)
	(T3) Calorimeter water in temp. trans. (degC)
	(T4) Calorimeter water out temp. trans. (degC)
	(T5) Exhaust Gas temp. trans. (Engine) (degC)
	(T6) Exhaust Gas temp. trans. (cal) (degC)
	(F7) Air Flow Transmitter (mmWC)
	(F8)Fuel Flow Transmitter (mmWC)
	(F9) Load Cell (kg)
	(P10)Cylinder Pressure Transducer (bars)
	(R12) Engine rpm Sensor



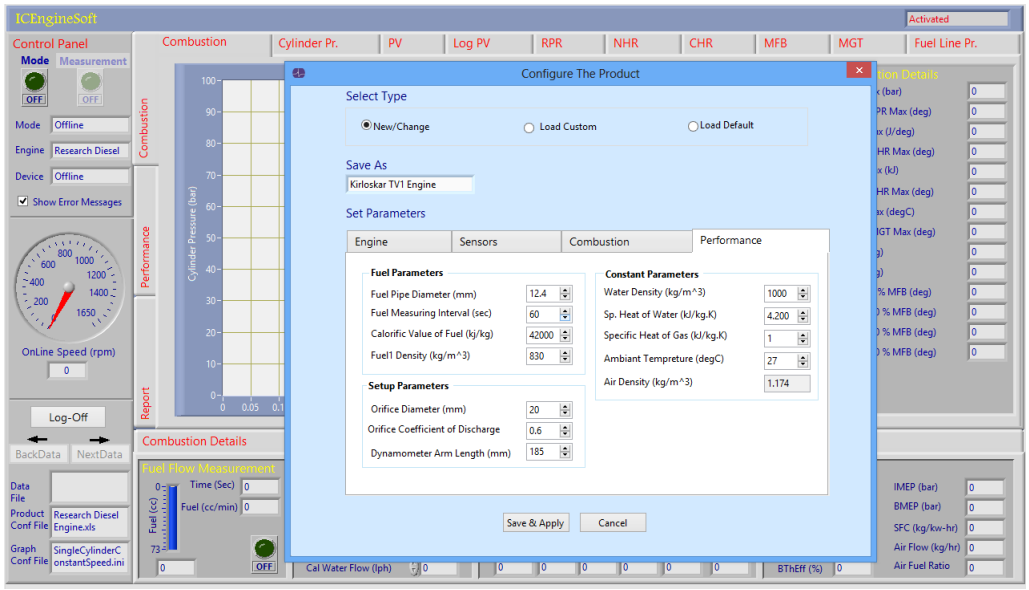
Combustion

Combustion Parameters	Combustion Parameters
Number Of Cycles: 10	Speed Scan Interval (msec): 2000
Pulses Per Revolution: 360	Fuel Line Pressure Reference: **Auto**
Cylinder Pressure Smoothing: 2	Cylinder Pressure Reference: **Auto**
Adiabatic Index: 1.41	Polytrophic Index: **Auto**
X-axis Scale Style: [(-ve) to (+ve)]	TDC Adjustment (deg**):** **Man**
Fuel Injection /Spark angle(deg. Before TDC):23	
	Noise Reduction Parameters
	Avg& Interpolate Segment: NO
	De-Noise the Signal: Yes



Performance

Fuel Parameters	**Constant Parameters**
Fuel Pipe Diameter(mm): **14.54**	Water Density (kg/m^3): 1000
Fuel Measuring Interval(Sec): 60	Specific Heat of Water (kj/kg.K): 4.200
Calorific Value of Fuel (kj/kg): 42000	
Fuel Density (kg/m^3): 830	Specific Heat of Gas (kj/kg.K): 1
	Ambient Temperature (degC): 27
Setup Parameters	Air Density (kg/m^3): 1.174
Orifice Diameter(mm): **35**	
Orifice Coefficient of Discharge: 0.6	
Dynamometer Arm Length(mm): **210**	



2 STUDY OF ENGINE PERFORMANCE (MANUAL MODE)

OBJECT

To study the performance of 2 cylinder, 4 stroke, CRDI Diesel engine connected to dynamometer in manual mode

PROCEDURE

- Ensure cooling water circulation for eddy current dynamometer, piezo sensor, engine cooling and calorimeter.
- Start the set up and run the engine at no load for 4-5 minutes.
- Gradually increase throttle to full open condition and load the engine simultaneously maintaining engine speed at @ 3600 RPM.
- Wait for steady state (for @ 3 minutes) and collect the reading as per **Observations**provided in "Cal238" worksheet in "Engine.xls".
- Gradually increase the load to decrease the speed in steps of @500 RPM up to @ 2000 RPM and repeat the observations.
- Fill up the observations in "Cal238" worksheet to get the results and performance plots.

3 Study of Pressure volume plot and indicated power

OBJECT

To draw pressure–crank angle plot, pressure volume plot and calculate indicated power of the engine.

PROCEDURE

- Run the engine set up at any load and store the observation in a data file or use previously stored data file in "Enginesoft" for indicated power calculation.
- Export the data file in ms excel worksheet. The pressure crank angle and volume data is available in excel.
- Refer "IP cal" worksheet in "Engine.xls". The sample worksheet shows pressure crank angle plot, pressure volume plot and indicated power calculation. The worksheet is for single cylinder four stroke engine with 180 observations per revolution.
- Copy the pressure readings from exported data file in to the IP _cal worksheet at the respective crank angle.
- Observe the Pressure crank angle diagram, pressure volume diagram and indicated power value. (The calculations are explained in theory part).

4 Maximum power test

OBJECT

To study the maximum power generated by engine.

PERFORMANCE TEST

- Ensure cooling water circulation for dynamometer and engine and calorimeter.
- Start the set up and run the engine at no load for 4-5 minutes.
- Gradually increase the load on the engine by rotating knob on dynamometer loading unit till the engine is fully loaded. (As load is increased further the speed drops significantly.)
- Note the reading as per **Observations**provided in "Cal238" worksheet in "Engine.xls".
- Gradually decrease the load.
- Change the compression ratio for next observation and repeat above steps.
- Fill up the observations in "Cal238" worksheet to get the results and performance plots.

5 BSFC and brake thermal efficiency test

OBJECT

To study the BSFC and brake thermal efficiency

PERFORMANCE TEST

- Ensure cooling water circulation for dynamometer and engine and calorimeter.
- Start the set up and run the engine at no load for 4-5 minutes.
- Gradually increase the load on the engine by rotating knob on dynamometer loading unit to @100% of load (Refer experiment 3 for full load)
- Note the reading as per **Observations** provided in "Cal238" worksheet in "Engine.xls".
- Gradually decrease the load.

Fill up the observations in "Cal238" worksheet to get the results and performance plots.

Components used

Components	Details
Engine	Make Mahindra, Model Maxximo, Type 2 Cylinder, 4 Stroke, Diesel CRDI with ECU, water cooled, Power 18.4Kw at 3600 rpm, Torque 55 NM at 2500rpm,stroke 83 mm, bore 84mm, 909cc,CR 18.5
Dynamometer	Make Technomech, Model TME100, Type Eddy current 100BHP@4500RPM.
Dynamometer controller	Make Technomech, Model TM-92E, Supply 230V AC,Variable speed Engine, Input PNP pulse from rpm sensor 0-30mV from load cell, Range 0-5000rpm.
Propeller shaft	Make Hindustan Hardy Spicer, Model 1260, Type A
Manometer	Make Apex, Model MX-104, Range 100-0-100 mm, Type U tube, Conn. 1/4`` BSP hose back side, Mounting panel
Fuel measuring unit	Make Apex, Glass, Model:FF0.090
Piezo sensor	Make PCB Piezotronics, Model S111A22, Range 5000 psi, Diaphragm stainless steel type & hermetic sealed
White coaxial teflon cable	Make PCB piezotronics, Model 002C20, Length 20 ft, Connections one end BNC plug and other end 10-32 micro
Crank angle sensor	Make Kubler, Model 8.KIS40.1361.0360Clamping/Synchro flange, 6x12.5mm shaft, IP64Logic level: RS422; Supply= 5VDCSquare wave O/P: A, A', B, B', 0, 0'Incr/turn: 360 PPR, Termination: 2m long axial cable
Data acquisition device	NI USB-6210 Bus Powered M Series Multifunction DAQ Device, NI DAQmx driver Software
Piezo powering unit	Make-Apex, Model AX-409.
Temperature sensor	Make Radix Type K, Ungrounded, Sheath Dia.6mmX110mmL, SS316, Connection 1/4"BSP (M) adjustable compression fitting
Temperature sensor	Make Radix, Type Pt100, Sheath Dia.6mmX110mmL,

	SS316, Connection 1/4"BSP(M) adjustable compression fitting
Temperature transmitter	Make ABUSTEK, Model : Fr Block, Input : Thermocouple (K), Range : 0 To 1200ºC, Output : 4-20 mA, Powersupply : 24 V DC, Dimension : 44 X 25 MM, , Precalibrated to 1200 Deg C
Temperature transmitter	Make ABUSTEK, Model : Fr Block, Input : PT-100, Range : 0 To 100ºC, Output : 4-20 mA, Powersupply : 24 V DC, Dimension : 44 X 25 MM, , Precalibrated to 100 Deg C
Load sensor	Make SensotronicsSanmar Ltd., Model 60001,Type S beam, Universal, Capacity 0-50 kg
Load indicator	Make ESD, Model Sleek 9010, 230VAC, retransmission output 4-20 mA
Power supply	Make Meanwell, model NES-15-24, O/P 24 V, 0.7 A
Digital voltmeter	Make Meco, 3.1/2 digit LED display, range 0-20 VDC, supply 230VAC, model SMP35S
Fuel flow transmitter	Make Yokogawa, Model EJA110E-JMS5J-912NN, Calibration range 0-500 mm H2O, Output linear
Air flow transmitter	Make WIKA, Model SL-1-A-MQA-ND-ZA4Z-ZZZ and output 4-20 mA, supply 10-30 Vdc, conn. 1/2"NPT(M), Range (-)25 - 0 mbar.
Rotameter	Make Eureka Model PG 5, Range 25-250 lph, Connection ¾” BSP vertical, screwed, Packing neoprene
Rotameter	Make Eureka, Model PG 6, Range 40-400 lph, Connection 1” BSP vertical, screwed, Packing neoprene
Pump	Pump make Kirloskar, Model KDS1.540, HP 1.5, Single phase, Size 32x25 Type Self priming
Battery	Make Exide, Model FEMO-DIN65, Cap. 12 V DC
Contact relay	Make Leone, Model P40FC – 2C, Supply – 240V AC, AC240V – 5900 ohms, Contact 30A, 250VAC

Calculations

Brake power (kw)

$$BP = \frac{2\pi NT}{60x1000}$$

$$= \frac{2\pi N(WxR)}{60000}$$

$$= \frac{0.785xRPMx(Wx9.81)xArmlength}{60000}$$

$$BHP = \frac{TxN}{75x60}$$

Brake means effective pressure (bar)

$$BMEP = \frac{BPx60}{\pi/4xD^2xLx(N/n)xNoOfCylx100}$$

n = 2 for 4 stroke
n = 1 for 2 stroke

Indicated power From PV diagram (kw)

X scale (volume) 1cm = ..m^3
Y scale (pressure) 1cm = ..bar
Area of PV diagram = ..cm^2

$$workdone/cycle/cyl(Nm) = AreaofPVdiagram \times Xscalefactor \times Yscalefactor \times 100000$$

$$IP = \frac{workdone/cycle/cyl \times (N/n) \times NoOfCyl}{60 \times 1000}$$

Indicated mean effective pressure (bar)

$$IMEP = \frac{IPx60}{\pi/4xD^2xLx(N/n)xNoOfCylx100}$$

Frictional power (kw)

$$FP = IP - BP$$
$$FHP = IHP - BHP$$
$$BHP = IHP - FHP$$

Brake specific fuel consumption (Kg/kwh)

$$BSFC = \frac{FuelflowIn\,kg/hr}{BP}$$

Brake Thermal Efficiency (%)

$$BThEff = \frac{BP \times 3600 \times 100}{FuelFlowIn\,Kg/hr \times CalVal}$$

$$BThEff = \frac{IThEff \times MechEff}{100} OR \frac{BHP}{FuelHP}$$

Indicated Thermal Efficiency (%)

$$IThEff = \frac{IP \times 3600 \times 100}{FuelFlowIn\,Kg/hr \times CalVal}$$

$$IThEff = \frac{BThEff \times 100}{MechEff}$$

Mechanical Efficiency (%)

$$MechEff = \frac{BP \times 100}{IP}$$

Air flow (Kg/hr)

$AirFlow = Cd \times \pi/4 \times d^2 \sqrt{2gh \times (Wden/Aden)}$ X3600 X Aden

Volumetric Efficiency

$$VolEff = \frac{AirFlow \times 100}{TheoreticalAirFlow}$$

$$= \frac{AirFlow \times 100}{\pi/4 \times D^2 \times Stroke \times (N/n) \times 60 \times NoOfCyl \times Aden}$$

Air fuel ratio

$$A/F = \frac{AirFlow}{FuelFlow}$$

Heat Balance (KJ/h)

a) $HeatSuppliedbyFuel = FuelFlow \times CalVal$

b) $HeatEquivalentToUsefulWork = BP \times 3600$

$$HeatEquivalentToUsefulWorkIn\% = \frac{HeatEquivalentToUsefulWork \times 100}{HeatSuppliedByFuel}$$

C) $HeatInJacketCoolingWater = F3 \times C_P W \times (T2 - T1)$

Where F3 is rate of Jacket cooling water, T2 is jacket water outlet temperature and T1 is jacket water inlet temperature.

$$HeatInJacketCoolingWaterIn\% = \frac{HeatInJacketCoolingWater \times 100}{HeatSuppliedByFuel}$$

d) Heat in Exhaust (Calculate $C_P$ex value):

$$C_P ex = \frac{F4 \times C_P w \times (T4 - T3)}{(F1 + F2) \times (T5 - T6)} ..KJ/Kg^0k$$

Where,

$C_P$ex Specific heat of exhaust gas kJ/kg^{0}K

C_{pw}	Specific heat of water		kJ/kg^{0}K
F1	Fuel consumption	kg/hr	
F2	Air consumption	kg/hr	
F4	Calorimeter water flow		kg/hr
T3	Calorimeter water inlet temperature		^{0}K
T4	Calorimeter water outlet temperature		^{0}K
T5	Exhaust gas to calorimeter inlet temp.		^{0}K
T6	Exhaust gas from calorimeter outlet temp.	^{0}K	

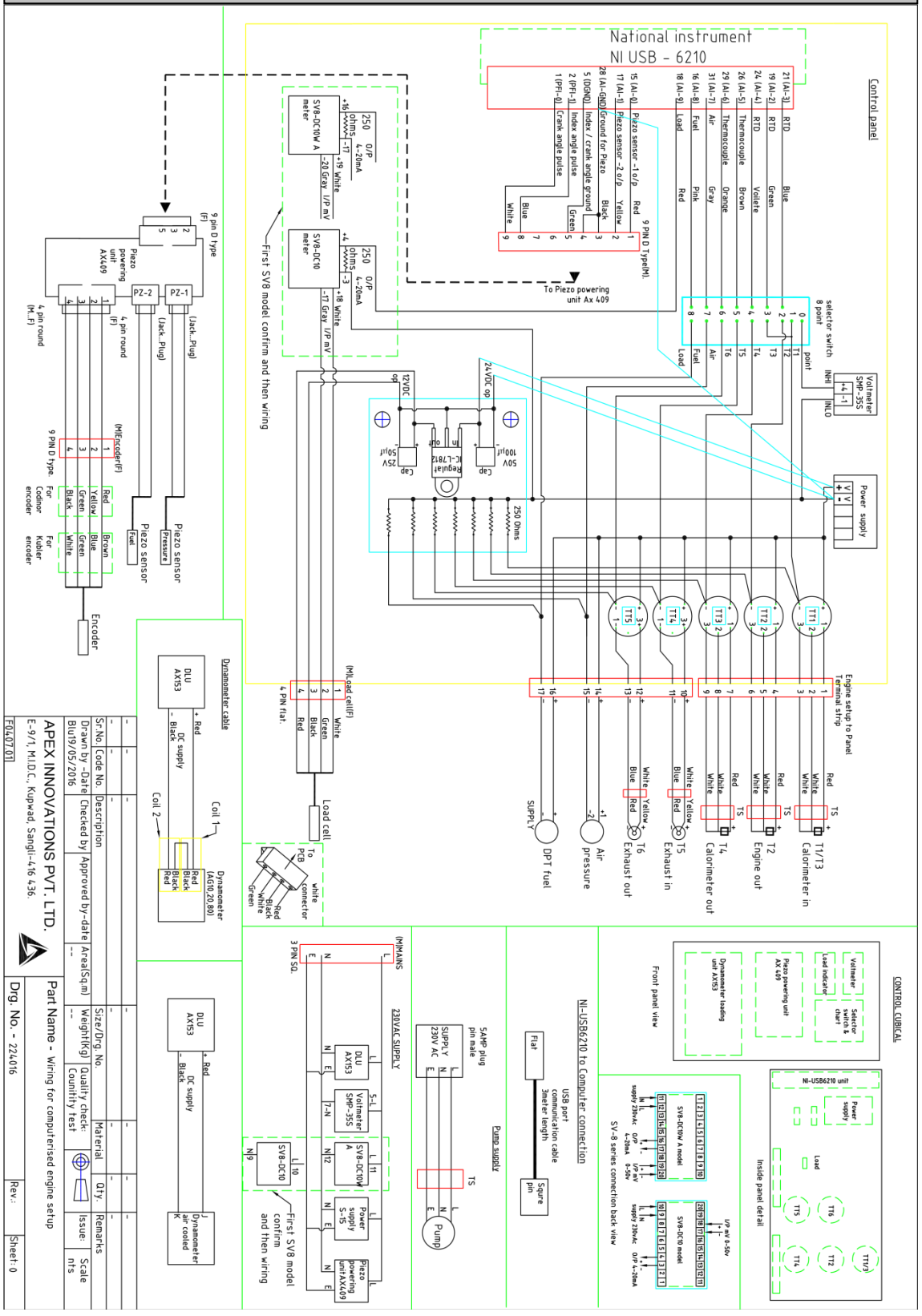
$$HeatInExhaust(KJ/h) = (F1 + F2) \times C_P ex \times (T5 - Tamb)$$

$$HeatInExhaust\% = \frac{HeatInExhaust \times 100}{HeatSuppliedByFuel}$$

e) Heat to radiation and unaccounted (%)

$$= HeatSuppliedByFuel\,(100\%) - \{(HeatEquivalentToUsefulWork(\%) + HeatInJacketCoolingWater(\%) + HeatToExhaust(\%)\}$$

Wiring diagram



Warranty

This product is warranted for a period of 12 months from the date of supply against manufacturing defects. You shall inform us in writing any defect in the system noticed during the warranty period. On receipt of your written notice, Apex at its option either repairs or replaces the product if proved to be defective as stated above. You shall not return any part of the system to us before receiving our confirmation to this effect.

The foregoing warranty shall not apply to defects resulting from:

Buyer/ User shall not have subjected the system to unauthorized alterations/ additions/ modifications.

Unauthorized use of external software/ interfacing.

Unauthorized maintenance by third party not authorized by Apex.

Improper site utilities and/or maintenance.

We do not take any responsibility for accidental injuries caused while working with the set up.

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