RESEARCHENGINE TEST SET UP

1CYLINDR, 4STROKE, MULTI-FUEL, VCR

with Open ECU

(Computerized)

Product Code

240PE

Instruction manual

Contents

Apex Innovations

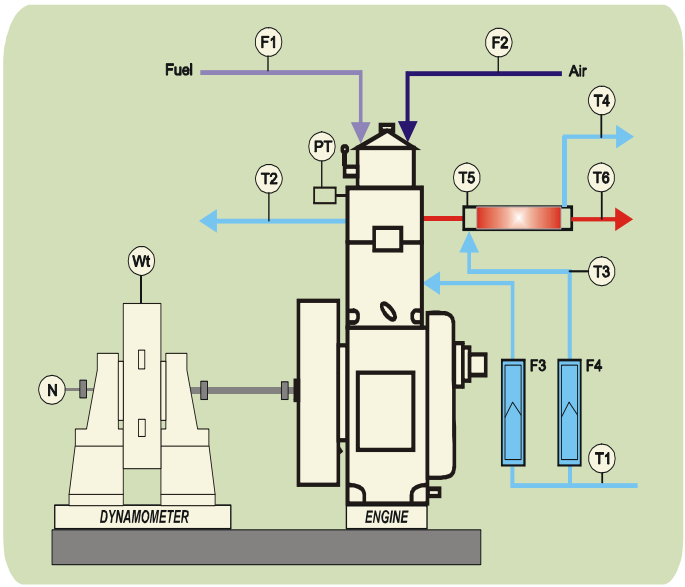
Description

The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to ECU Petrol or from ECU Petrol to Diesel mode by following some procedural steps. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed ***tilting cylinder block*** arrangement. In Diesel mode fuel injection point and pressure can be manipulated for research tests. In Petrol mode fuel injection time, fuel injection angle, ignition angle can be programmed with open ECU at each operating point based on RPM and throttle position. It helps in optimizing engine performance throughout its operating range. Air temp, coolant temp, Throttle position and trigger sensor are connected to Open ECU which control ignition coil, fuel injector, fuel pump and idle air. Set up is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and calorimeter water flow measurement.A battery, starter and battery charger is provided for engine electric start arrangement.

The setup enables study of VCR 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, heat balance and combustion analysis.

Labview based Engine Performance Analysis software package "Enginesoft" is provided for on line engine performance evaluation.

PE3 series software package is provided for programming open ECU for petrol mode operation of the engine.



Schematic arrangement

(Performance evaluation)

Specifications

Product	Research Engine test setup 1 cylinder, 4 stroke, Multi-fuelVCR with open ECU for petrol mode (Computerized)
Product code	240PE
Engine	Type 1 cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm. Capacity 661 cc. Diesel mode: Power 3.5 KW, Speed 1500 rpm, CR range 12:1-18:1.Injection variation:0- 25 DegBTDC ECU Petrolmode:Power 3.5 KW @ 1500 rpm, Speed range 1200-1800 rpm, CR range 6:1-10:1
Dynamometer	Type eddy current, water cooled, with loading unit
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit, Type: Duel compartment, with fuel metering pipe of glass
Calorimeter	Type Pipe in pipe
Piezo sensor	Combustion: Range 5000 PSI, with low noise cable Diesel line: 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.
Engine control unit	PE3 series ECU, full build potted enclosure.
Sensors for ECU	Air temp, coolant temp, Throttle position and trigger.
Engine Controlhardware	Fuel injector, Fuel pump, ignition coil, idle air
Digital voltmeter	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	"ICEngineSoft" Engine performance analysis software
ECU software	peMonitor&peViewer software.

Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm

Shipping details

Gross volume 1.33m^3, Gross weight 796kg, Net weight 639kg

Installationrequirements

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**

- Provide 5A, three pin socket with switch (2 Nos.) for engine set up
- Provide additional 5A, three pin sockets for computer and peripherals

Water supply

Continuous, clean and soft water supply@ 1000 LPH, at 10 m. head. Provide valve with 1" BSP hose terminal 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

L3300 mm x W3200 mm x H1700 mm (Refer foundation drawings)

Drain

Provide suitable drain extension arrangement (Drain PVC pipe 75 MM /2.5" size)

Exhaust

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

Foundation

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

Fuel, oil

Diesel@5 lit.

Petrol@10 lit.

Lubrication Oil @ 3.5 lit. (20W40)

Packingslip

Total no. of boxes: 10, Volume: 2.08 m^3, Gross wt.: 773 kg. Net wt. 642 kg

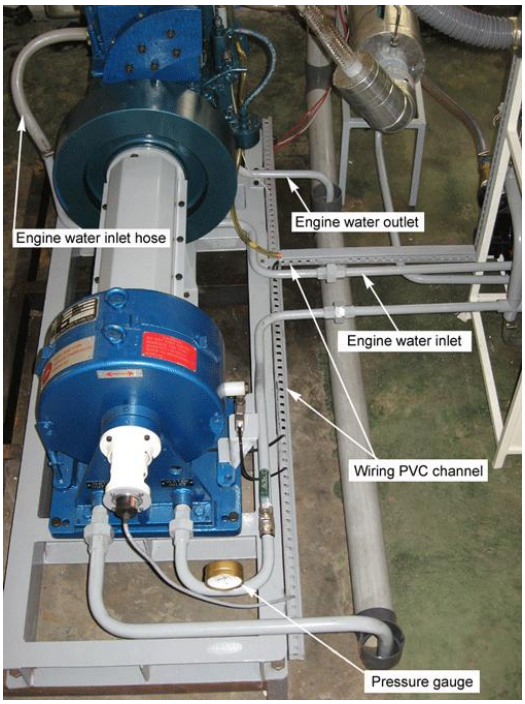
Box No.1/10	Engine set up assembly Size W1600xD670xH1120 mm; Volume:1.20m^3	Gross weight: 444kg Net weight: 444kg
1	Engine test setup assembly Engine + Dynamometer	1 No.
Box No.2/10	Engine panel box structure Size W800xD475xH500 mm; Volume:0.19m^3	Gross weight: 46kg Net weight: 25kg
1	Structure assembly consisting of Rotameters with piping (2) Dynamometer loading unit clamp (1) Fuel distributor unit with cock (1)	1 No.
Box No.3/10	Engine panel box Size W990xD475xH500 mm; Volume:0.24m^3	Gross weight: 75kg Net weight: 52kg
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.4/10	Calorimeter Size W725xD250xH325 mm; Volume: 0.06m^3	Gross weight: 28kg Net weight: 15kg
1	Calorimeter	1 No.
2	Calorimeter support structure with pad	1 No.
Box No.5/10	Exhaust pipe Size W900xD200xH200 mm; Volume: 0.04m^3	Gross weight: 16kg Net weight: 10kg
1	Exhaust pipe	1 No.
Box No.6/10	Pump Size W300xD225xH300 mm; Volume:0.02m3	Gross weight: 14kg Net weight: 7kg
1	Pump	1 No.
Box No.7/10	Battery Size W150xD225xH250 mm; Volume:0.01m3	Gross weight: 19kg Net weight: 8kg
1	Battery	1 No.
Box No.8/10	Dash board panel Size W500xD400xH300 mm; Volume:0.06m^3	Gross weight: 35kg Net weight: 20kg
1	Dash board panel box Battery charger (1)	1 No.

	Petrol ECU(1) Wiring for petrol ECU Fuel throttle unit(1) Fuel tank with pump (1)	
Box No.9/10	Engine piping Size W1250xD450xH350mm; Volume: 0.20m^3	Gross weight: 58Kg Net weight: 41kg
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	Fuel Glass tube 2Nos (one spare)	1 No.
3	Funnel for fuel fill	1 No.
4	Wiring PVC channel set (4 pieces)	1 No.
5	Starting kick/Handle	1 No.
6	Exhaust extension pipe with socket	1 No.
7	Pump bracket	1 No.
8	Air box connection	1 No.
9	Starter	1 No.
10	Calorimeter exhaust outlet flange	1 No.
11	Engine head for petrol with support and rod	1 No.
Box No.10/10	Engine wiring Size W500xD400xH300 mm; Volume:0.06m^3	Gross weight: 38kg Net weight: 20kg
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	Load cell	1 No.
7	Piezo sensors	2 Nos.
8	Piezo cables	2 Nos.
9	Temp sensors (5)	1 No.
10	Encoder with flange, rubber and coupling	1 No.
11	Head packing, Spark plug each 2Nos	1 No.
12	Fuel piping with connection	1 No.

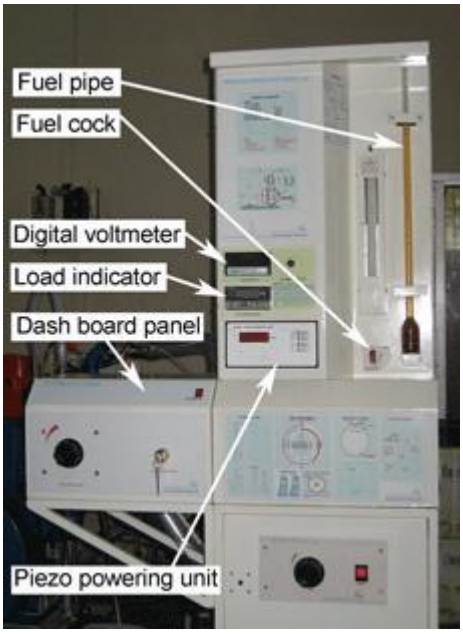
13	Air manifold with Fuel injector	1 NO.
14	Engine spanner set, Screw driver small, Spark plug spanner, VCR spanner 7/16, Allen key 8mm and Tool kit	1 No.
15	Fuel caps(2), Teflon tape(2) & Gasket shellac(1)	1 No.
16	Set of instruction manuals Instruction manual CD (Apex), NI driver CD (1) Enginesoft CD, PE3 Instruction manual CD, Cable for NI USB 6210, DP transmitter, Dynamometer, Pump, Kirloskar engine maint. Calibration sheets for load cell and piezo sensor	1 No.

Installations

- 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 packing's, paper boxes and 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. 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.Inside the Rotameters plastic rods are inserted to arrest the movement of respective floats. These rods are to be removed.



- Keep *Engine panel box structure* near *Engine setup assembly*. Note the C type clamp provided for clamping the dynamometer loading unit.
- 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 three bolts.
- Fit the Dash board panel with support structure on the Panel box structure with four bolts.

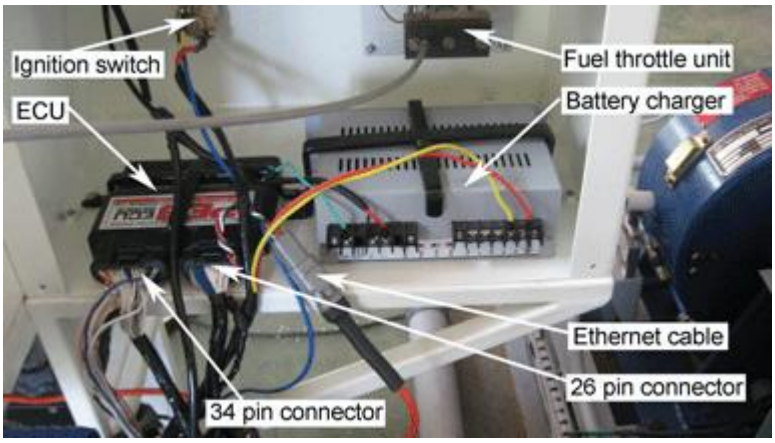


- Collect Piezo powering unit (Ax409), Dynamometerloading unit (AX155), *Load indicator* (SV8 series)*and Digital voltmeter* (SMP35) from "Engine wiring" box.
- Remove the covers of Piezo powering unit and Dynamometer loading unit and confirm that all components inside are at proper location and tightly 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 4 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.
- Collect the piping pieces form "Engine piping box".Clean the pipes internally to remove any dust and particles.Complete the piping as per match marks as follows:
    - Connect *Engine water inlet* from engine cooling Rotameter to water inlet on engine body.
    - Connect *Engine water outlet*. Connect *Engine water outlet hose*between the outlet pipe and engine body.

  - 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 wiring *PVC channel set*.
- Collect the wiring set from *Sensors* bag and fit 5 temp sensors at respective places.
  - RTD T1/T3 at the inlet water at pump outlet.
  - RTD T2 at the Engine outlet water on the engine head.
  - RTD T4 at the calorimeter water outlet.
  - Thermocouple T5 at the Exhaust inlet of calorimeter and
  - Thermocouple T6 at the exhaust outlet of calorimeter.

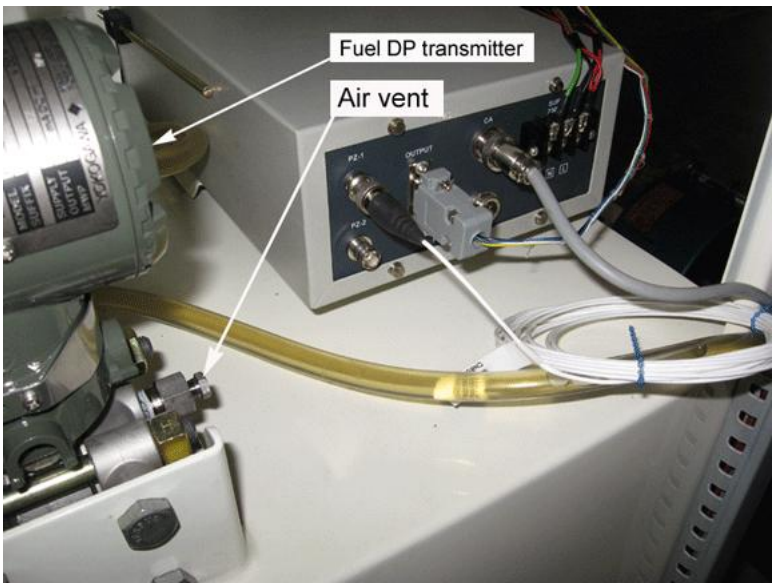
  Route the wiring from PVC wiring channels.
- Collect Electric supply *cable* packed in packing (named as *Sensors)* and connect LNE terminals to the transmitter panel at supply 230V. Connect its 3 pin (F) connector to Dynamometer loading unit at Supply. Connect male 3 pin connectorto Electric supply available at the site. Route the cable through wiring channel.
- Connect cablefrom Crank angle sensor, 4 pin round (F), to CA of Piezo powering unit.
- Connect cable from Load cell, 4 pinflat (F), to Load on transmitter panel.
- Remove black cap on Piezo sensor andconnect 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 NIUSB 6210 from Engine Panel and connect to Computer. The cable is short in length. A spare cable of extra length is also supplied.

- Fit dash board panel for ECU petrol on left side of the engine panel box by nut bolts.
- Fit fuel throttle unit, battery charger and ECU and wiring harness in the dashboard panel.



Commissioning

- Remove top cover on the rocker box of the engine. Fill lubrication oil (SAE20W40 or equivalent) in the rocker box. About3.5 lit 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. You may fill two different fuels, for testing the fuels. Fill **Diesel** in one of the fuel tanks and **Petrol** in other tanks as marked on the tanks. Use Fuel funnel for filling. Put fuel caps on the fuel tanks.
- Fuel tank with fuel pump fit on bottom structure pipe and fuel tank overflow pipe connect to petrol filling pipe.
- 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.



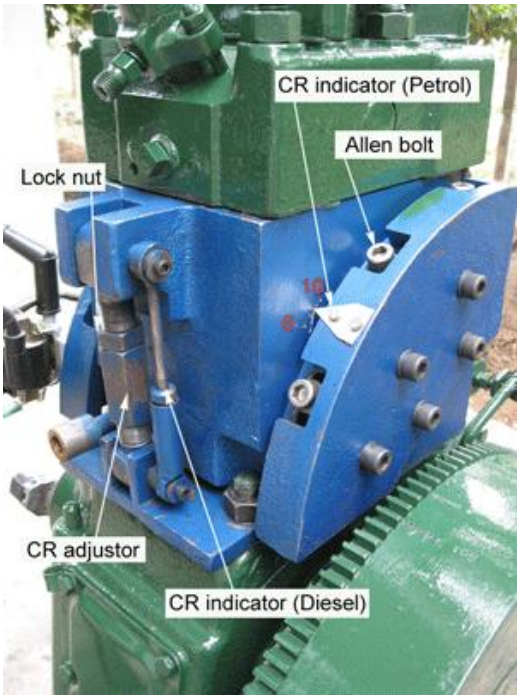
- Fill water in the manometer up to "0" mark level.
- Ensure that Jack bolts under dynamometer are lowered for free movement of the dynamometer body.
- Switch on electric supply of the panel box and ensure that Piezo powering unit, load indicator and voltmeter are ON.
- **TDC adjustment:**
    - Keep the Decompression lever on the rocker box in vertical position and rotate the flywheel slowly in clockwise direction (Viewed from dynamometer end) till the E (Encoder) mark on the flywheel matches

with the reference pointer provided on the engine body. This rotation movement should be unidirectional.

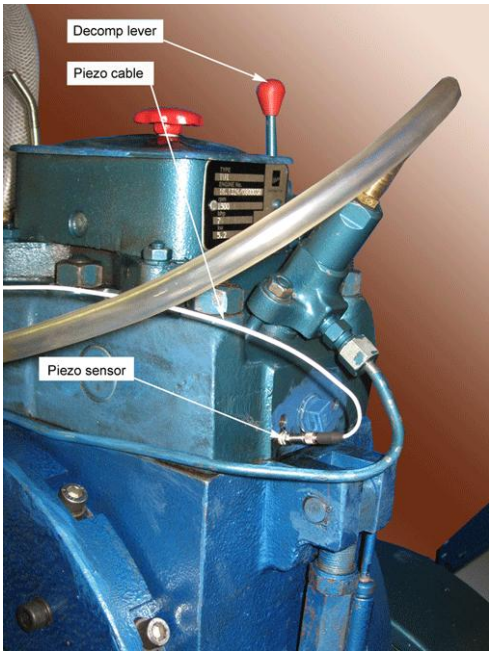
- Check if the TDC light on the Piezo powering unit is lit. If not adjust the crank angle sensor as follows:
- Loosen the four screws on the flange provided for clamping the crankangle sensor on the mounting bracket.
- Ensure that crank angle sensor body is free to rotate about its axis. Rotate the sensor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

- **Compression Ratio adjustment:**
- Slightly loosen 6 Allen bolts provided for clamping the tilting block.
- Loosen the lock nut on the adjuster and rotate the adjuster so that the compression ratio is set to "maximum". Refer the marking on the CR indicator.
- Lock the adjuster by the lock nut.
- Tighten all the 6 Allen bolts gently.
- You may measure and note the centre distance between two pivot pins of the CR indicator. After changing the compression ratio the difference (Δ) can be used to know new CR.



- Switch on the pump after providing electric supply to it and ensure water circulation through engine, calorimeter and dynamometer.
- Keep the Load knob on the dynamometer loading unit at minimum position.
- **Engine starting (Diesel mode):**
- Ensure that all foundation bolts, propeller shaft bolts and Allen bolts of tilting block (of VCR arrangement) are properly tightened.
- Ensure that Engine stop lever is free and can be pulled towards engine cranking side for stopping the engine.
- For first start after installation, loosen the fuel inlet pipe to the injector. Crank the engine slowly (with Decompression lever in vertical position) till fuel starts dribbling out from the loosened nut. Then tighten the nut.
- Ensure that Decompression lever (Decomp lever) is in horizontal position and CR is set at @ 17.5 to 18.
- Start the engine ignition switch so that the engine will be cranked by battery.
- If engine does not start you may check valve setting as explained in "**Engine Valve setting"**.



- Keep water circulation on, Set @150 lph and 100 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.
- Load the engine up to 12 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.
- Ensure that engine is cooled before switching off the pump.
- For software installation on the computer proceed to Software section
- **Engine Valve setting**

This procedure to be followed only if engine does not start or pressure crankangle diagram shows some pressure values at the start of suction.)

- Open the cover on the rocker box. Rotate the flywheel slowly and observe the rocker movement. The cranking side rocker is for inlet air and flywheel side rockeris for exhaust air. The "Engine fuel pump side end" of each rocker is pushed up by the valve rods below. Due to this the front end (injector side end) goes down to open the respective valves (Inlet/exhaust). For alternate rotation of flywheel at TDC position, both rockers move simultaneously.
- Adjust the TDC mark marked as T on the flywheel with the pointer. (Note there are two marks one marked as E and other as T. E marking is to be used for crankangle sensor adjustment for PO diagram). Ensure that when we bring the flywheel near these markings both rockers should move i.e. piston is at the start of new cycle.

- Refer the valve timing diagram on the engine panel. The Inlet valve should open 4.5 degree before TDC and exhaust valve should close 4.5 deg after TDC. Make a marking of @ 16 mm (4.5 degree) on both sides of TDC mark.
- Rotate the flywheel in anticlockwise direction for 60 degrees and slowly rotate in clockwise direction up to the first mark before TDC (Here the inlet valve should open. Exhaust valve is already in open position i.e. rocker is in operated position). Adjust the Tappet clearance by using ring spanner no. 18 such that the clearance if any is removed and rocker just starts opening the inlet valve.
- Further rotate the flywheel in clockwise direction to next marking of 4.5 degrees after TDC. At this position the exhaust valve should fully close. Adjust the tappet clearance so that there is no clearance in exhaust rocker. (Note: The decompration lever should be in horizontal position)
- Ensure that inlet valve opens at 4.5 degree BTDC and exhaust valve closes 4.5 degree ATDC.

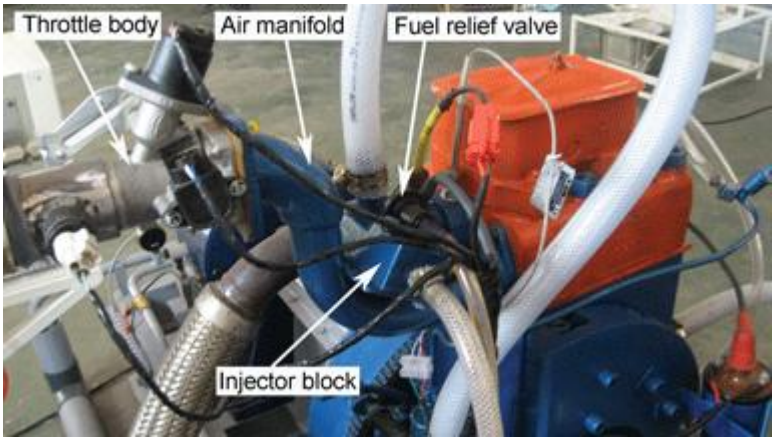
Diesel to Petrol

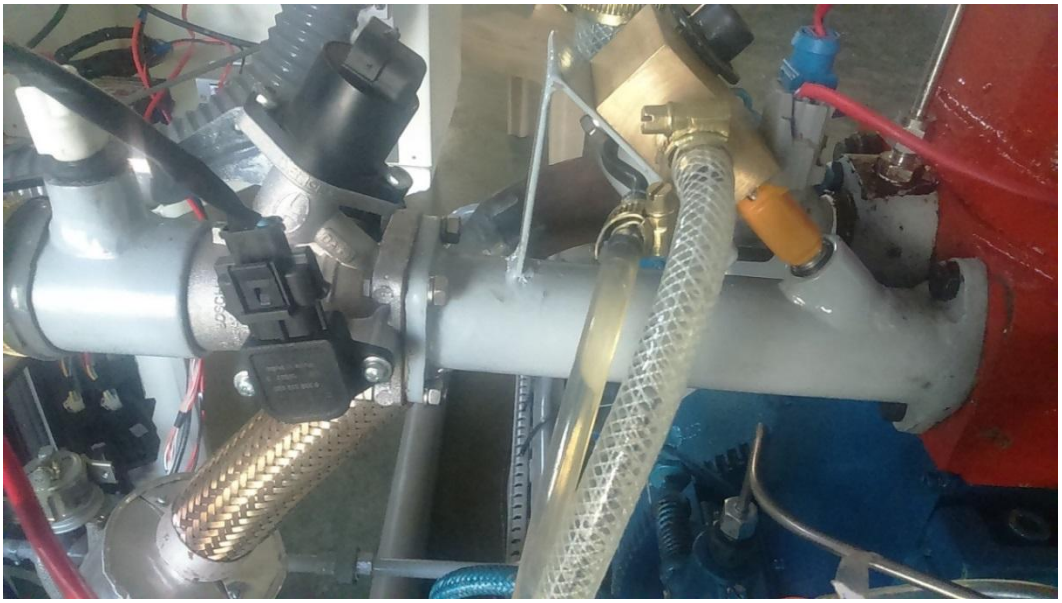
Removing Diesel Head

- Disconnect the Battery connection positive and negative and put at safe position.
- Switch off and disconnect electric supply of engine panel
- Close the Fuel cock at the outlet of "Diesel tank".
- Keep Fuel cock on engine panel in "Tank" position. At fuel junction bracket, open the drain cock and collect the Diesel from fuel measuring unit and fuel line.
- Disconnect the low noise cable from combustion chamber Piezo sensor.
- Disconnect the low noise cable from fuel line Piezo sensor, mark it for identification.
- Remove Piezo sensor from the engine head and keep it at secured and safe place.
- Disconnect the high pressure fuel pipe and overflow pipe connected to the injector. Connect these pipes to each other by inserting plastic pipe over high pressure metal pipe.
- Disconnect air duct pipe from engine head bend and remove CI bend.
- Remove exhaust connection from engine head
- Remove water outlet from engine head along-with water outlet temperature sensor.
- Loosen and remove 4 nuts which clamp engine head to the linear block. (Use 9/16 spanner)
- Remove push rods (2 nos.)

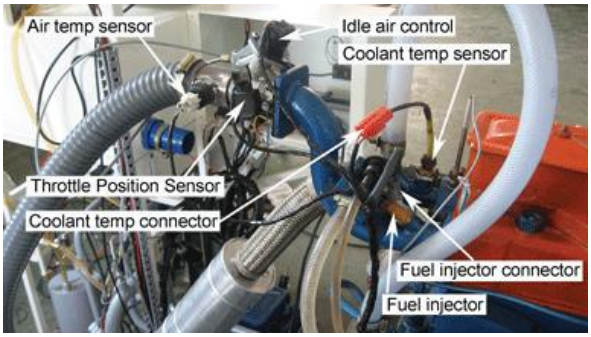
Fitting Petrol Head

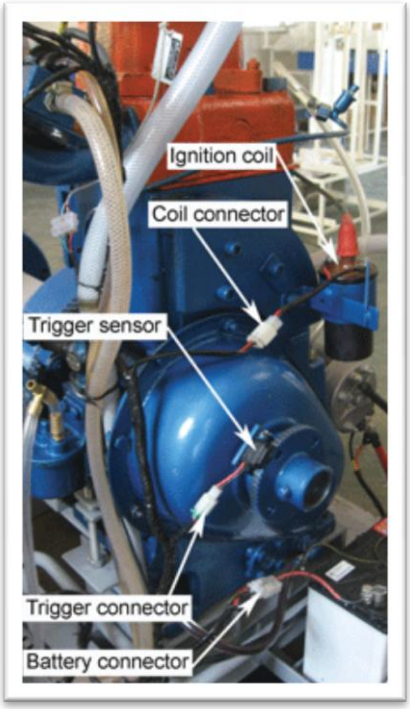
- Adjust the compression ratio to 10:1 on petrol scale.
- Use new head packing. Apply thin grease layer to head packing before use.
- Insert 2 push rods for Petrol operation. These push rods are longer in length when compared with those for Diesel operation.
- Remove the cover lid on the rocker box. Fit the head assembly (Engine head + air manifold + Throttle body) on liner block. Ensure that push rods are properly inserted in the engine head. Tighten the 4 nuts (Use 9/16W5 flat spanner). During tightening the nuts rotate the flywheel and ensure smooth movement of valve rods. Fit the cover lid.

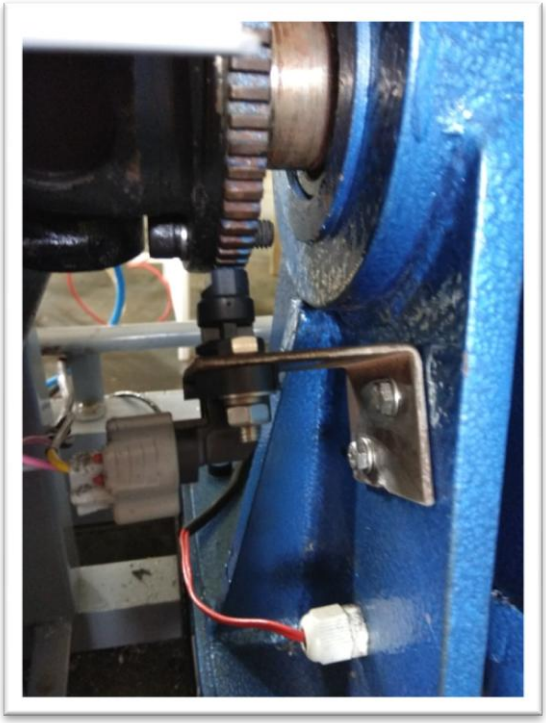




- Connect the Engine outlet water connection to the engine head (with outlet water sensor)
- Connect exhaust flange to the engine head.
- Connect the air duct pipe from air box to the throttle bodyinlet.
- Connect accelerator cable to throttle body.
- Fit the Piezo sensor in engine head and connect low noise cable to Piezo sensor.
- Remove spark cable from the spark plug at ignition coil and connect the cable to spark plug in the engine head.
- Connect the coolant temp sensor connector







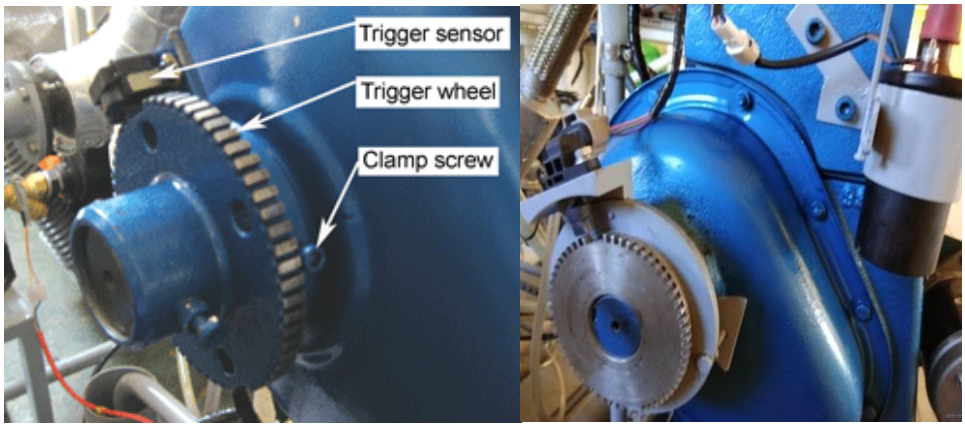
- Connect Trigger sensor connector, Ignition coil connector and battery connector

- Keep Fuel cock on the engine panel at "Tank" position.
- Close Diesel and Petrol cocks at the fuel Junction bracket.
- Close the Diesel cock and open the Petrol cock at the fuel tank outlet.
- Collect @ 50 ml petrol from drain cockand close the drain cock.
- Open the petrol cock at fuel junction bracket.
- After all other preliminary checkups start the engine.

Trigger point adjustment

Trigger point adjustment

- It is presumed that engine is set for Petrol operation.
- Take the decompression lever to vertical position.
- Rotate and adjust the flywheel to match the pointer with "T" mark.
- Ensure that the trigger sensor tip is aligned with centre line of first tooth on the trigger wheel. First tooth is measured after gap of two missing teeth in the direction of clockwise rotation of trigger wheel.For adjusting the trigger sensor loosen the clamp screws and rotate the bracket on which trigger sensor is fitted. Then clamp the bracket by tightening the clamp screws.
- Shift decompression lever to horizontal position and start the engine.



Petrol to Diesel

Removing Petrol Head

- Disconnect the Battery connection positive and negative and put at safe position.
- Switch off and disconnect electric supply of engine panel
- Close the Fuel cock at the outlet of "Petrol tank".

- Keep Fuel cock on engine panel in tank position. At fuel junction bracket, open the drain cock and collect the petrol from fuel measuring unit and fuel line. Disconnect petrol pipe from Injector block and collect the petrol in that line from drain cock.
- Close the Petrol cock on the Fuel junction bracket.
- Open the Diesel cock of Diesel Fuel tank and collect @ 50 ml Diesel from drain cock. Close the cock on Diesel fuel tank and close the drain cock.
- Disconnect Spark plug and insert the Spark plug cable in a plug provided near ignition coil. (This plug is provided for supporting the plug cable)
- Disconnect the Piezo sensor and low noise cable.
- Remove Piezo sensor and keep it at secured and safe place.
- Disconnect air duct pipe from throttle body inlet.
- DisconnectCoolant temp connector, ignition coil connector, trigger connector and battery connector of the wiring harness.
- Remove exhaust connection from engine head (Use ¼ "BSW spanner).
- Remove water outlet from engine headalong-with temperature sensor (Use ¼ "BSW spanner).
- Loosen and remove 4 nuts which clamp engine head to the liner block. (Use 9/16W5 flat spanner)and put the head assembly (Engine head + air manifold + Throttle body) on stand provided near the engine panel box
- Remove push rods and put in stand pipe(2 nos.)

Fitting Diesel Head

- Check the condition of packing, if damaged use new head packing. Apply thin grease layer to head packing..
- Inset push rods (2 Nos) for Diesel operation. These push rods are shorter in length when compared with those for petrol operation.
- Remove the cover lid on the rocker box. Fit the head on linear block. Ensure that push rods are properly inserted in the engine head. This operation needs two persons to ensure proper assembly of push rods. Tighten the 4 nuts (Use 9/16W5 flat spanner). During tightening the nuts rotate the flywheel and ensure smooth movement of valve rods. Fit the cover lid.
- Connect the Engine outlet water connection to the engine head (with outlet water temperature sensor)
- Connect exhaust connection to the engine head.
- Connect the duct pipe from air box to the engine head.
- At the delivery of the fuel pump, the high pressure metal pipe is connected to plastic pipe. Disconnect this connection and connect the high pressure pipe to

inlet of the fuel injector. Connect the plastic pipe to the overflow of the injector.

- Connect low noise cable of fuel line Piezo sensor.
- Fit the Piezo sensor (Use spanner size 6-7) and connect low noise cable to Piezo sensor.
- At fuel junction bracket, ensure that drain cock is closed. Petrol cock is closed and Diesel cock is open.
- Loosen the Vent plug on fuel pump. Ensure fuel cock on engine panel is in tank position. Open the Fuel cock at the outlet of Diesel tank
- Close the vent on fuel pump as the Diesel comes out.
- Ensure that the fuel injection is adjusted as described in "**Injection point adjustment to company setting".**
- Ensure the CR is adjusted @ 17-18. Hand cranks the engine to ensure smooth movement of the piston.
- After all other preliminary checkups start the engine.

Injection point adjustment

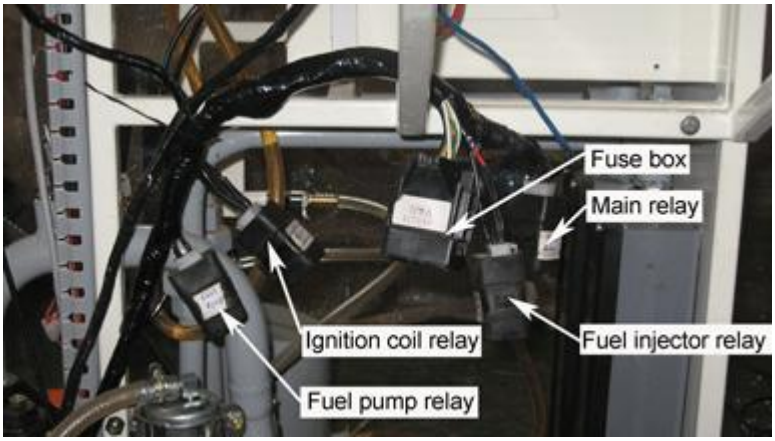
Injection point adjustment to company setting

- It is presumed that engine is set for Diesel operation and Diesel fuel is available at fuel pump.
- Remove the high pressure fuel pipe at the outlet of fuel pump.
- Take the decompression lever to vertical position.
- The company set injection point is marked "F" on the flywheel which is @ 23 Degrees before TDC (@ 8 teeth on the flywheel).
- Rotate the flywheel (by hand) in clockwise direction and observe the fuel spillage from fuel pump. Note the spillage point on the flywheel. Note the difference between spillage point and company set injection point.
- Turn the injection point adjusting nut in one direction@ ¼ turn. Check the difference between Fuel spillage point and company set injection point. If the difference is reduced repeat the adjustment in same direction. If the difference is increased rotate the adjusting nut in opposite direction. Repeat the adjustment till the difference is reduced to minimum.
- To start the engine with company set injection point, connect the high pressure fuel pipe to the injection pump and shift decompression lever to horizontal position.

Injection point adjustment to desired point (On line adjustment)

- It is presumed that engine is running in Diesel mode and On-line Diesel injection plot is being displayed on the monitor using software.
- Note the injection point displayed on the monitor. It is the point where maximum Diesel line pressure occurs.
- Turn the injection point adjustment nut gradually and note its effect on Diesel injection plot. The Diesel injection plot shifts horizontally to retard/advance injection point depending upon the direction of rotation. Adjust the nut till desired injection point is obtained.

Following photograph shows position of relays and fuse box.



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.

ECU Petrol: Reference documents

- *PE3 user manual*
- *AN001_600F4i_Trigger-Sync*
- *h40*
- *AN000_Determining_Trigger_and_Sync_Settings_2*
- *PE3 Series Datasheet 10-24-11*

Troubleshooting

Note: 1 For component specific problems refer components' manual

2 For wiring problems refer drawing "Wiring240PE".

Problems	Possible causes / remedies
Engine does not start	**Diesel mode:** • Decompression lever in vertical position. Make it horizontal • Low Battery voltage: Recharge battery • No fuel injected: Remove air from air vent on the fuel pump • Clogged injector: Remove injector and check the fuel injection spray while engine is manually cranked. • VCR setting low: Set VCR to 17-18 • Fuel injection point disturbed: Set to company setting • Dynamometer loaded: Switch off dynamometer loading unit or adjust load to minimum • Improper valve setting: The valve setting procedure is described below. **Petrol mode** • Decompression lever in vertical position. Make it horizontal • Low Battery voltage: Recharge battery • Spark plug damaged/short • VCR setting wrong : Set VCR to 10 • Dynamometer loaded: Switch off dynamometer loading unit or adjust load to minimum • Check trigger wheel setting • Ensure working of fuel pump when ignition key is switched on • Ensure Sensors and Outputs are connected to ECU
Dynamometer does not load the engine	• Faulty/ loose wiring from dynamometer loading unit to dynamometer • NoDC voltage at the outlet of dynamometer loading unit. Check DLU for loose connection • No free movement of dynamometer body due to raised jack bolts below dynamometer body

	• Water inlet outlet hoses connecting dynamometer body below the dynamometer may be very hard.
Faulty air flow	• Air hose leakage at connections between air box and engine.
Faulty fuel flow	• Air trap in pressure signal line to fuel transmitter • Improper closing of fuel cock.
Software does not work	• Faulty or wrong USB port • Virus in computer • Loose connections, improper earthing
Faulty indicated power	• TDC setting disturbed. Readjust TDC setting(refer commissioning). • Check configuration data
Faulty pressure crank angle diagram	• Improper earthing • Adjust Plot reference for cylinder pressure in setup constants such that suction stroke pressure just matches the zero line. • If peak pressure is just after 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 indication	• Check the connection between thermocouple, RTD, transmitters, Digital voltmeter. Note that yellow cable of thermocouple is positive and red is negative. • Open or damaged temperature sensor

Components used

Components	Details
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, Model TV1, stroke 110 mm, bore 87.5 mm. 661 cc, CR 18, Modified to VCR engine CR range 12 to 18 with additional head for petrol
Dynamometer	Make Technomech, model TMEC10, 10BHP@1500-5000 RPM, without load cell with instruction manual
Dynamometer Loading unit	Make Apex, Model AX-155. Type constant speed, Supply 230V AC.
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:FF0.012
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
Engine control unit	PE3 series ECU, full build potted enclosure.
Throttle body	Make Tata motors Model used in TATA Nano car
Fuel injector	Make Denso Model: Used with Maruti800 car
Fuel pump	Make Denso Model: Used with Maruti800 car
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 ABUS, model SV8-DC10, 85 to 270VAC, 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, 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 ¾” BSP vertical, screwed, Packing neoprene
Pump	Make Kirloskar, Model Mini 18S, HP 0.5, Size 1” x 1”, Single ph 230 V AC

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

$$work done/cycle/cyl(Nm) = Area of PV diagram \times Xscale factor \times Yscale factor \times 100000$$

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

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)

$$BSFC = \frac{Fuel flow In kg/hr}{BP}$$

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):

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

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

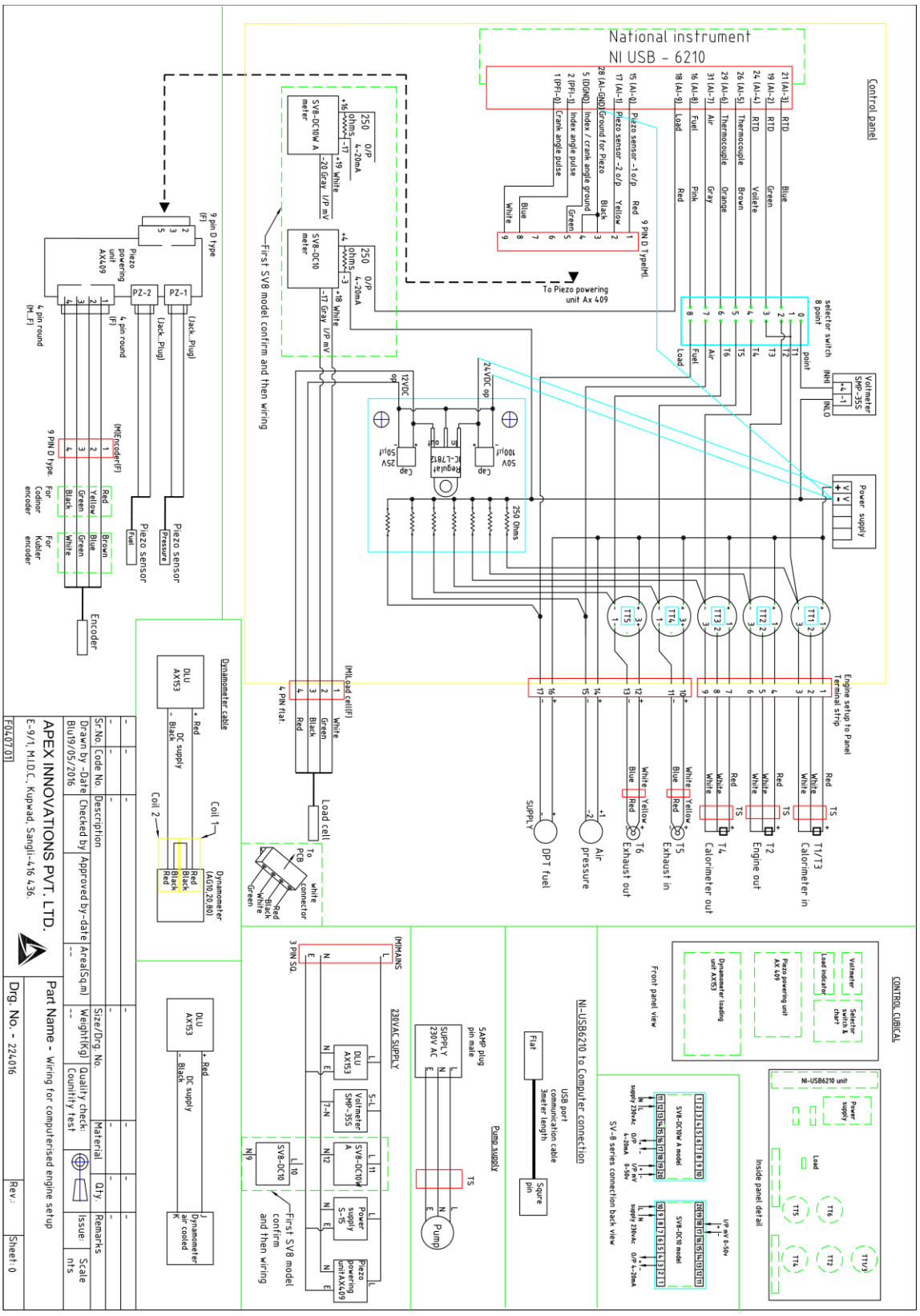
$$HeatInExhaust(KJ / h) = (F1 + F2) \times C_P ex \times (T5 - Tamb)$$

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

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.

Apex Innovations Pvt. Ltd.

E9/1, MIDC, Kupwad, Sangli-416436 (Maharashtra) India

Telefax:0233-2644098, 2644398

Email: support@apexinnovations.co.inWeb: www.apexinnovations.co.in