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# MATERIALS AND METHODS: DEVELOPMENT OF EXPERIMENTAL SETUP

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## ABSTRACT

*A test rig was developed to carry out the present investigations. Necessary instruments and equipment were setup after calibration for measurement of important engine parameters. The test engine setup consisted of Kirloskar AV1 single cylinder direct injection, water-cooled, 4-stroke diesel engine with a rated output of 3.7 kW at 1500 r/min. The test engine has been modified to measure various parameters required to determine its performance. To make the engine to work on dual fuel mode, arrangements were made to induct LPG through the intake manifold.*

***Keywords:*** *Test Rig, Calibration, Engine Parameters, Test Engine, Electrical Dynamometer.*

## Introduction

A schematic layout of the experimental setup is shown in Fig. 1. The developed test facility included the following arrangements:

- Test engine to which an electrical dynamometer is coupled.
- LPG induction through intake manifold.
- Probes for measuring engine coolant, intake air and exhaust gas temperature.
- Burette and stop watch for fuel consumption measurement.
- Airflow orifice manometer and settling drum.
- Flow meters to measure LPG and water flow rate.
- Flush mounted quartz pressure pickup for cylinder pressure measurement.
- Crank angle encoder having a resolution of 180° crank angle.
- Oscilloscope for displaying pressure-crank angle (P-$\theta$) diagrams.
- Instrumentation for measurement of exhaust emissions.

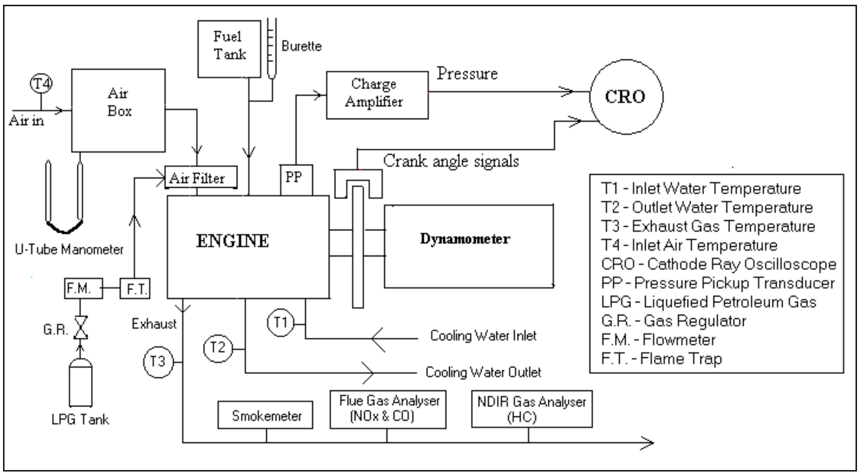

**Fig. 1 Schematic Diagram of test Setup**

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### Engine

Kirloskar make single cylinder engine (AV1) was used for the present investigations; as it is widely used in agriculture i.e., for pumping water, threshing, flour mills, electricity generation, etc. The technical specifications of the engine are given in Table 1.

### Dynamometer

Power-star make electric dynamometer was coupled to the engine for measuring torque. It consisted of an alternator to which electric bulbs were connected to load the engine. The specifications of the alternator used are given in Table 2.

**Table 1: Specifications of Kirloskar AV1 diesel engine**

**Model:** AV1 - 5 hp

**Specifications**

| No. of Cylinders | One |
|---|---|
| Type | Vertical, 4-stroke engine |
| Fuel Injection | Direct Injection (DI) |
| Engine speed | 1500 rpm, constant speed |
| Cooling | Water cooled (run-through or thermo-siphon) |
| Air supply | Naturally aspirated |
| Filter | Paper element filter |
| Bore x Stroke | 80 x 110 mm |
| Cubic Capacity | 0.553 l |
| Compression Ratio | 16.5 : 1 |
| Rated Output as per BS5514/ISO 3046/IS 10001 | 3.7 kW (5.0 hp) at 1500 r/min |
| SFC at rated hp (1500 r/min) | 245 g/kW.h(180 g/bhp.h) |
| Lubrication | Force Feed Lubrication to main and large end bearings and camshaft bush |
| Lubricating Oil Consumption | 1.0% of SFC maximum |
| Lubricating Oil Sump Capacity | 3.3 l |
| Fuel supply system | Gravity feed |
| Fuel Tank Capacity | 6.5 l |
| Fuel Tank re-filling time period | Every 6 hours engine running at rated output |
| Engine Weight (dry) w/o flywheel | 114 kg |
| Weight of flywheel | 33kg - Standard |
| Rotation while looking at the flywheel | Clockwise.<br>Optional - Anticlockwise |
| Power Take-off | Flywheel end.<br>Optional-Gear end half or full speed |
| Starting | Hand start with cranking handle. |

**Table 2: Specifications of Electric Dynamometer**

| S. No. | Technical Specifications | Description |
|---|---|---|
| 1. | Make | Power star |
| 2. | kVA | 3.5 |
| 3. | Voltage | 230 Volt |
| 4. | Current | 14 A |
| 5. | Frequency | 50 C/s |
| 6. | Rating | Continuous |
| 7. | Revolutions per minute | 1500 |

### Air Flow Measurement

An air box having dimensions 45×45×50 $cm^3$ with U-tube manometer was used to measure airflow to the engine. It was used to dampen out the pulsation of air. An orifice of diameter 20 mm was fitted on one of the sidewalls of the air box. The outlet was given at the bottom of the box through which it was connected to the air filter mounted on the engine. The quantity of inducted air was obtained with the help of following equation, Air inducted/second = $C_d \times A_{orifice} \times (2 \times g \times h_w \times \rho_w / \rho_a)^{1/2}$

Where,

$C_d$ = 0.6

$A_{orifice}$ = 0.00031415 $m^2$

$h_w$ = Manometer reading (m)

$\rho_w$ = Density of water (1000 $kg/m^3$)

$\rho_a$ = Density of air (1.157 $kg/m^3$)

**Fuel Flow Measurement**

The pilot fuel (diesel, biodiesel and its blends) was measured with the help of a measuring glass burette of 100 $cm^3$ capacity. The burette was connected to fuel tank and the engine through a T-valve. While measuring fuel consumption the supply from the fuel tank was cut off by the valve and only the burette supplied the fuel to the engine. The time taken by the engine to consume a fixed volume of fuel was measured with the help of a digital stopwatch. This volume divided by the time gave the volumetric flow rate.

LPG was supplied to the engine through a hole that was drilled in the wall of the air filter bowl and to which a nipple was soldered. The mass flow rate of gas was measured before introducing it in the engine. LPG stored in cylinder at a pressure of approximately 13.8 bar was reduced to approximately 1 bar through the pressure regulator.

For measuring the mass of gas supplied, a weighing balance was utilized. The flow valve was calibrated so as to have gas flow rate of 28.84 g/h, 146 g/h, 388.88 g/h and 840 g/h whenever required. A flame trap was provided to suppress back flash if any from the intake manifold.

A schematic diagram of flame trap is depicted in Fig. 2. Any back flash from the engine is quenched by the water present in the flame trap before it reaches the LPG inlet pipe.

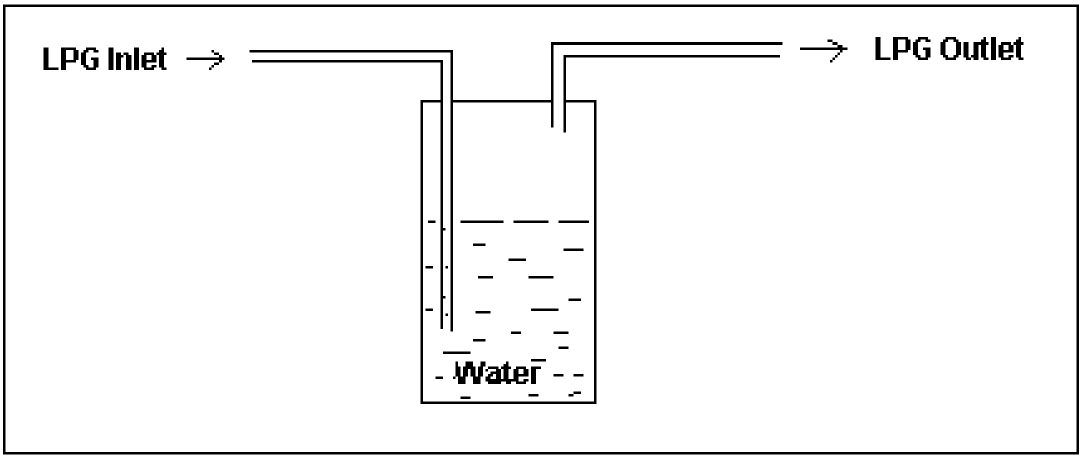


Fig. 2: Schematic Diagram of Flame Trap

**Temperature Measurement of Intake Air, Exhaust Gases and Cooling Water**

Thermocouples attached to a six-channel selector switch and digital panel meter were installed at required points on the engine to measure temperature of intake air, exhaust gases and cooling water.

**Variation of Injector Opening Pressure**

By adjusting a screw on top of the injector, the spring load on the injector needle was varied leading to change in injector opening pressure.

**Cylinder Pressure Measurement**

In order to measure the instantaneous pressure in side the cylinder, Kistler make pressure pick up (type no. 601A) was connected to the cylinder head with the help of a connecting nipple (type no. 6421A20) and a water-cooled adopter (type no. 6509) through a specially designed and fabricated pressure pickup adopter housing made on the cylinder head.

Pressure pickup consists of a piezoelectric sensor, which converts mechanical quantities (pressure in this case) directly into an electric charge. The charge produced is proportional to the force acting on the quartz crystal contained in the sensor. The sensitivity of the sensor is stated in pC/M.U. The electronic circuit is designed so that the power supply and signal transmission use the same two-pole cable. A standard coaxial cable (type no.1631C3) was used to connect sensor to the charge meter along with a data acquisition and analysis system. Specifications of the pressure pickup used are given in the Table 3.

**Table 3: Technical Specifications of Pressure Pickup 601A**

| S. No. | Technical Data | Unit | Range |
|---|---|---|---|
| 1. | Range | bar | 0 - 250 |
| 2. | Calibrated partial ranges | bar<br>bar | 0 - 25<br>0 - 2.5 |
| 3. | Overload | bar | 500 |
| 4. | Sensitivity | PC/bar | -16 |
| 5. | Natural frequency | kHz | 150 |
| 6. | Linearity | %FSO | ≤ ± 0.5 |
| 7. | Acceleration sensitivity | bar/g | < 0.001 |
| 8. | Operating temperature range | °C | -196 to 200 |
| 9. | Temperature Coefficient of sensitivity | °C-1 | < 10-4 |
| 10. | Insulation resistance at 20 °C | Ω | ≥1013 |
| 11. | Shock resistance | g | 10,000 |
| 12. | Capacitance | PF | 5 |
| 13. | Weight | g | 1.7 |
| 14. | Connector, Teflon insulator | | M4×0.35 |

Kistler make Miniature Charge Amplifier (Type 5039A) having Range I adjusted to 5000 pC (max.) was used to measure in-cylinder pressure. The charge amplifier was operated from power line, received the charge from the piezoelectric sensor and converted it into a proportional voltage. The sensitivity of the charge amplifier was 2mV/pC.

The data obtained were transferred to a 2-channel Tektronix make TDS1002 monochrome 60 MHz digital storage oscilloscope to display the cylinder pressure and crank angle on screen graphically.

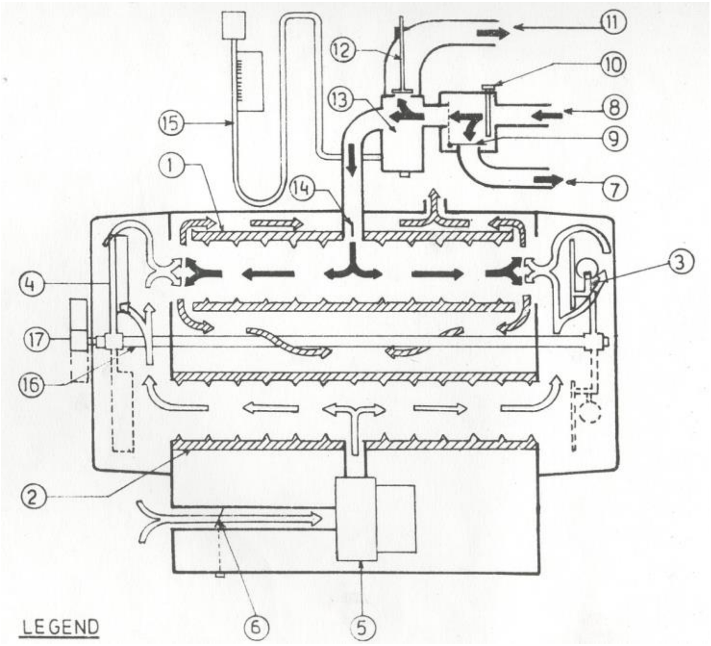
### Crank Angle Measurement

A magnetic pickup was placed adjacent to a timing disc mounted on the flywheel of the engine. Magnetic pickup (vicinity switch) with the help of timing disc sent signals of crank angle to the oscilloscope, so that P-$\theta$ diagram could be obtained. An Olympus make digital camera was used to capture the photographs of pressure and crank angle.

### Smoke Density Measurement

Exhaust smoke density was measured with the help of Envirotech APM 700M Hartridge Smoke meter. A schematic diagram of the smoke meter used is shown in Fig. 3. The smoke meter works on a comparative basis. It contains two dimensionally and optically similar tubes. The reference tube is connected to the clean air blower. Air is drawn from the clean air inlet through a damper. The smoke tube is connected to the smoke inlet via the smoke bypass valve. This inlet tract contains a temperature sensor, moisture trap and has a pressure relief valve controlled outlet, a pick off for the manometer connection and a vane at the tube entry.

The light source and photoelectric cell are each mounted on an arm pivoted on each end of a spring located control shaft, which was operated by a control knob. The opacity of the smoke sample was compared to a clean air sample by first taking reading through the clean air tube to set the zero, then moving the light and photoelectric cell to the smoke tube for an instantaneous comparative reading of the opacity of the tube sample. For repetitive and accurate results the pressure of the smoke sample was carefully controlled. Limiting factors such as condensation, temperature, smoke distribution and constant light intensity for the light source were held within practical limits.



1. Smoke tube
2. Clean air tube
3. Light source
4. Photo-cell Assembly
5. Blower
6. Damper
7. Exhaust pipe
8. Smoke inlet
9. By-pass Valve shutter
10. Temperature Sensor
11. Excess Pressure Outlet
12. Pressure Relief Valve
13. Moisture Trap Assembly
14. Deflector Vane
15. Manometer Assembly
16. Shaft
17. Control Knob

**Fig. 3: Schematic Diagram of Smokemeter**

### Measurement of CO and $\mathrm{NO_x}$

Carbon monoxide (CO) and Nitrogen oxides ($\mathrm{NO_x}$) in engine exhaust were measured with the help of Madur make GA-12-Pocket Gas Analyzer. The instrument detects the concentration of gas elements with the help of independent electrochemical sensors. The electrochemical cell indications are proportional to the volume concentration of the detected elements expressed in ‘parts per million’ (ppm).

### Measurement of HC

Fuji make NDIR (Non Dispersive Infrared) automotive gas analyzer was used for the measurement of hydrocarbons (HC) in the engine exhaust emissions. This analyzer is based on the principle that hetroatomic gases absorb infrared energy at distinct and separated (more or less) wavelengths, with the absorbed energy raising the temperature (and pressure) of the confined gas. A schematic diagram of the analyzer is shown in Fig. 4.

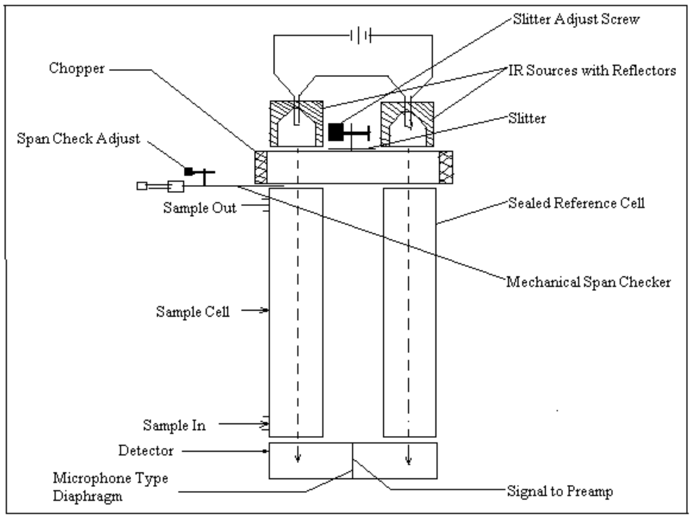


**Fig. 4: Schematic Diagram of NDIR Gas Analyzer**

## Conclusion

Thus, combustion in CI engine depends upon several factors such as type of fuel, injection pressure, injection advance, compression ratio, intake temperature, coolant temperature, fuel temperature, supercharging, engine speed, type of combustion chamber and the load on engine. In the investigations carried out, all the parameters had been kept constant except for fuel and load on engine. The effect of the variable factors on combustion is discussed below with the help of peak cycle pressure variation and P-$\theta$ diagrams.

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