3. RUSTON OIL ENGINE PERFORMANCE TEST

OBJECT

To carry out a test at constant load and constant speed in order to determine:

Mean effective pressure
Indicator power
Brake power
Indicated thermal efficiency
Brake thermal efficiency
Mechanical efficiency
And to draw up an energy balance.

PROCEDURE

Start cooling water. Load predetermined equal weights on the brake wheel belt. Start the engine and adjust cooling water flow rate so that its outlet temperature is 48°C to 60°C (water flow rate between 2.25 and 4.5 kg/minute) when the engine is running steadily.

Duration of the test is 20 minutes. The following readings are to be taken at intervals of 4 minutes:

1. Speed, N
2. Spring balance reading (brake load), W
3. Cooling water flow rate, Q
4. Cooling water inlet temperature, T_{IN}
5. Cooling water outlet temperature, T_{OUT}
6. Exhaust gas temperature, T_e

The ambient temperature, T_a, should also be recorded.

Indicator diagram

Each student should take one indicator diagram. The engine indicator spring number, K, kPa/mm, will be given on the indicator spring. Determine the mean height of the diagram, h, mm.

Mean effective pressure, Pme – h x K kPa.

Fuel consumption

While engine is running on oil from the tank, fill the measuring cylinder on the left hand scale pan. The pointer is now just to the left of the zero. Close the valve on the line from the tank and open the valve on the measuring cylinder line so that engine runs on oil from the cylinder. When the pointer passes zero, start the stop watch and remove 100 gm from the right hand scale pan. When the pointer again reach the zero mark, stop the stop watch and record this time taken to consume 100 gm of oil.

DO NOT ALLOW THE MEASURING CYLINDER TO COMPLETELY EMPTY.

Repeat at least 3 times during the test.

NOTE

1. All readings must be neatly recorded in the table provided. This table must be signed by the lecturer or technician in charge.

2. A neat and correctly labeled line diagram of the apparatus must be submitted. You should also submit a labeled diagram of the engine indicator.

RUSTON OIL ENGINE

READING

TIME, MINUTE:	0	4	8	12	16	20	MEAN
SPEED, N RPM							
LOAD, W lbs							
kg							
kN							
COOLING WATER:							
a) FLOW RATE							
Q lb/MINUTE							
$Q \times 10^3$ kg/s							
b) TEMPERATURES							
T_{IN} °C							
T_{OUT} °C							
GASS TEMPERATURES							
a) EXHAUST, T_e, °C							
AMBIENT, T_a, °C							
OIL FLOW RATE							
a) WEIGHT mf lb							
kg							
b) TIME t seconds							
$m \times 10^6$ kg/s							

Signed:______________________________ Date:_______________

CALCULATIONS

1) Mean effective pressure: P_{me} kPa
   Calculated P_{me} from the indicator diagram

2) Indicated power:

   $$\text{i.p.} = \frac{P_{me} LAN}{2 \times 60} \quad \text{kW}$$

   L = stroke in metres

   A = piston area $\frac{\square d^2}{4}$ m^2 (d in metres)

   N = engine speed in RPM

3) Brake power:

   $$\text{b.p.} = \frac{2\square NT}{60}$$

   T = Torque = FR, Nm
   F = Force = Wg, N
   W = Spring balance reading, kg
   R = D/2 = Brake wheel radium, m

☐ b.p. = $\frac{2☐NWgR}{60 \times 1}$ kW

4) Friction power
f.p. = i.p. – b.p. kW

5) Energy from oil
E_f = (H.C.V.) x ____ kW

6) Energy to cooling water

E_{cw} (Q) (C_p) (T_{OUT} – T_{IN}) kw
Cp = Mean specific heat of cooling water
Calculate at (T_{IN} + T_{OUT})/2 °C

7) Energy to exhaust gases
Ee = (m_e) (C_{pe}) (T_e-T_a) kW
M_e = m_f + m_a = mf

8) Indicated thermal efficiency
$n_{i.t.} = \frac{i.p.}{E_f}$

9) Brake thermal efficiency
$n_{b.t.} = \frac{b.p.}{E_f}$

10. Mechanical efficiency
$n_m = \frac{b.p.}{i.p.}$

ENERGY BALANCE

ITEM	KW	$\frac{X}{Ef}$ x 100%
E_f		100
b.p.		
E_{cw}		
E_e*		
Others By difference		

* If orsat appraratus gas analysis data is not available, calculate (Ee + others) by difference.
i.e. E_f – (b.p. + E_{cw})

ENGINE DATA

Compression ratio	16:1
Bore, d nm	127.0
Stroke, L nm	241.3
Brake wheel diameter, D, nm	825.5
H.V. of fuel, kJ/kg	44,200
Engine rating at 500 RPM, kW	6.0 (5.97)

REFERENCES

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2. Eastop, T.P. and McConkey, A.
Applied thermodynamics for engineers and technologists; ELBS/LONGMANS.

3. Joel, Rayner
Basic engineering thermodynamics in SI units; LONGMANS.

3. stone, Introduction to internal combustion engines.

4. THE TWO STAGE RECIPROCATIVE AIR COMPRESSOR

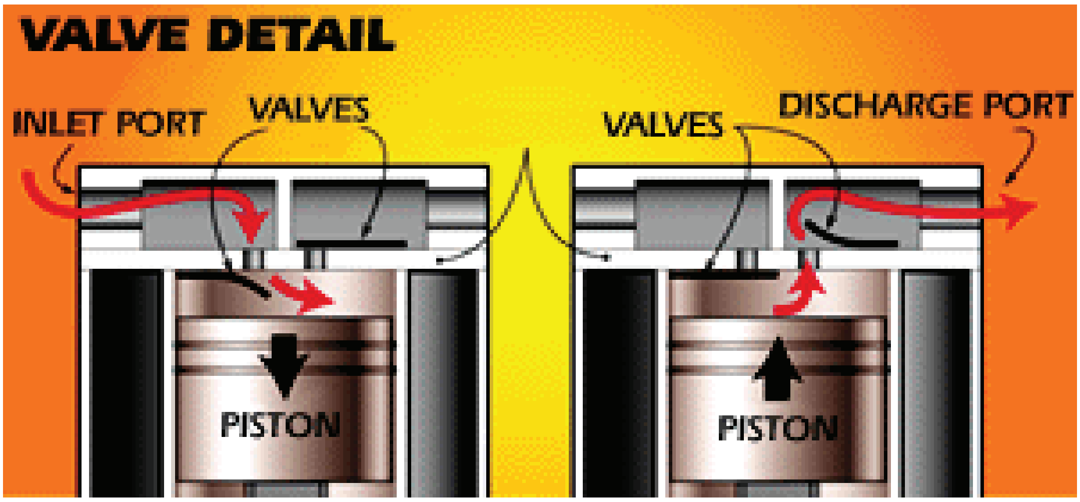
PLANT

Air compressor types

While there are compressors that use rotating impellers to generate air pressure, positive-displacement compressors are more common and include the models used by homeowners, woodworkers, mechanics and contractors. Here, air pressure is increased by reducing the size of the space that contains the air. Most of the compressors you'll run across do this job with a reciprocating piston.

Like a small internal combustion engine, a conventional piston compressor has a crankshaft, a connecting rod and piston, a cylinder and a valve head. The crankshaft is driven by either an electric motor or a gas engine. While there are small models that are comprised of just the pump and motor, most compressors have an air tank to hold a quantity of air within a preset pressure range. The compressed air in the tank drives the air tools, and the motor cycles on and off to automatically maintain pressure in the tank.

At the top of the cylinder, you'll find a valve head that holds the inlet and discharge valves. Both are simply thin metal flaps–one mounted underneath and one mounted on top of the valve plate. As the piston moves down, a vacuum is created above it. This allows outside air at atmospheric pressure to push open the inlet valve and fill the area above the piston. As the piston moves up, the air above it compresses, holds the inlet valve shut and pushes the discharge valve open. The air moves from the discharge port to the tank. With each stroke, more air enters the tank and the pressure rises.



As the piston moves down, the vacuum created allows outside air to push open the inlet valve (left). During compression (right), the inlet valve shuts while air is pressed into tank.

Typical compressors come in 1- or 2-cylinder versions to suit the requirements of the tools they power. On the homeowner/contractor level, most of the 2-cylinder models operate just like single-cylinder versions, except that there are two strokes per revolution instead of one. Some commercial 2-cylinder compressors are 2-stage compressors–one piston pumps air into a second cylinder that further increases pressure.

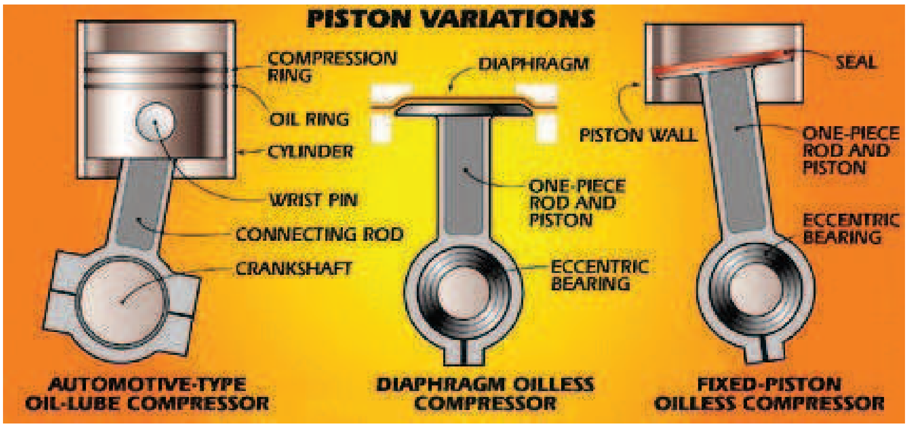
Compressors use a pressure switch to stop the motor when tank pressure reaches a preset limit–about 125 psi for many single-stage models. Most of the time, though, you don't need that much pressure. Therefore, the air line will include a regulator that you set to match the pressure requirements of the tool you're using. A gauge before the regulator monitors tank pressure and a gauge after the regulator monitors air-line pressure. In addition, the tank has a safety valve that opens if the pressure switch malfunctions. The pressure switch may also incorporate an unloader valve that reduces tank pressure when the compressor is turned off.

Many articulated-piston compressors are oil lubricated. That is, they have an oil bath that splash-lubricates the bearings and cylinder walls as the crank rotates. The pistons have rings that help keep the compressed air on top of the piston and keep the lubricating oil away from the air. Rings, though, are not completely effective, so some oil will enter the compressed air in aerosol form.

Having oil in the air isn't necessarily a problem. Many air tools require oiling, and inline oilers are often added to increase a uniform supply to the tool. On the down side, these models require regular oil checks, periodic oil changes and they must be operated on a level surface. Most of all, there are some tools and situations that require oilfree air. Spray painting with oil in the airstream will cause finish problems. And many new woodworking air tools such as nailers and sanders are designed to be oilfree so there's no chance of fouling wood surfaces with oil. While solutions to the airborne oil problem include using an oil separator or filter in the air line, a better idea is to use an oilfree compressor that uses permanently lubricated bearings in place of the oil bath.

A variation on the automotive-type piston compressor is a model that uses a one-piece piston/connecting rod. Because there is no wrist pin, the piston leans from side to side as the eccentric journal on the shaft moves it up and down. A seal around the piston maintains contact with the cylinder walls and prevents air leakage.

Where air requirements are modest, a diaphragm compressor can be effective. In this design, a membrane between the piston and the compression chamber seals off the air and prevents leakage.



A positive displacement compressor compresses air by reducing the size of the space that contains the air. In most cases, this is achieved with a piston. Piston type and lubrication method are two variables that affect compressor design and application.

Compressor power

One of the factors used to designate compressor power is motor horsepower. However, this isn't the best indicator. You really need to know the amount of air the compressor can deliver at a specific pressure.

The rate at which a compressor can deliver a volume of air is noted in cubic feet per minute (cfm). Because atmospheric pressure plays a role in how fast air moves into the cylinder, cfm will vary with atmospheric pressure. It also varies with the temperature and humidity of the air. To set an even playing field, makers calculate standard cubic feet per minute (scfm) as cfm at sea level with 68 degrees F air at 36% relative humidity. Scfm ratings are given at a specific pressure–3.0 scfm at 90 psi, for example. If you reduce pressure, scfm goes up, and vice versa.

You also may run across a rating called displacement cfm. This figure is the product of cylinder displacement and motor rpm. In comparison with scfm, it provides an index of compressor pump efficiency.

The cfm and psi ratings are important because they indicate the tools that a particular compressor can drive. When choosing a compressor, make sure it can supply the amount of air and the pressure that your tools need.

The Lab Equipment

The Broom and Wade two stage compressor has been designed for laboratory use. It comprises to LP cylinders mounted in the same casting, and separated from the single HP cylinder by the driving motor and a clutch. Both LP and HP cylinders are water cooled. The driving motor is of the AC commutator type and the stator is trunnion mounted so that the reaction torgue may be measured. Speed control is by means of an induction regulator through which the motor is supplied. Both LP and HP cylinders are fitted with mechanical indicators, the drum being eccentrically driven from the crank-shaft. For two stage operation the air after delivery from the LP stage is passed through a watch copied intercooler before entering the HP cylinder. After delivery from the HP cylinder the air may be passed though an after cooler before entering the receiver. One outlet pipe from the receiver is fitted with a sharp-edged orifice upstream of which is fitted a control valve. The pressure drop across the orifice may be measured by means of a U-tube containing water and the gauge pressure downstream of the orifice is measured in a similar manner. This enables the determination of the mass flow rate under steady state conditions, the control valve being opened gradually when the required delivery pressure in the receiver is reached, until the pressure in the receiver remains constant, and the orifice is passing exactly the amount of air delivered by the compressor. The water cooling circuit through the cylinder jacket and the intercooler and after cooler may be arranged such that the flows are in series or in parallel and provision is made for the measurement of the rate of flow though each component of the plant and also the temperature at inlet and outlet. These measurements are required only if any energy balance is to be determined. Each student must take one indicator diagram, and include it in his report. Thermometers are also provided for the measurement of air temperature at inlet to and outlet from each component.

OBJECT

The purpose of the experiment is to determine the performance characteristics of the compressor when operating at a fixed speed and varying delivery pressures. This entails the determinations of the air horsepower (ahp), shaft horsepower (shp) mechanical efficiency mass flow rate, volumetric efficiency, and isothermal efficiency.

PROCEDURE

1. Adjust the cooling water flow rates.
2. Start compressor and adjust speed to 400 rev/min.

3. Open orifice control valve gradually when receiver pressure is 50 ibf/in^2 gauge, such that the receiver pressure remains constant.
4. When steady state conditions are obtained take readings at 4 minute intervals for a duration of 12 minutes. During this time take 1 indicator diagram from each of the LP and HP cylinders.
5. Repeat this procedure at pressure intervals of approximately 30 ibf/in^2 up to a deliver pressure of 170 ibf/in^2.

OBSERVATIONS

A. Air Temperature

1. Ambient (to be taken at beginning and end of each test).
2. LP Cylinder inlet.
3. LP Cylinder outlet.
4. Intercooler inlet.
5. Intercooler outlet.
6. HP Cylinder inlet.
7. HP Cylinder outlet.
8. After cooler inlet.
9. After cooler outlet.
10. Orifice outlet.

B. Shaft Horsepower

1. Torgue arm load
2. Speed.

C. Pressures

1. Barometric pressure (at end of test).
2. Receiver pressure.
3. Orifice manometer readings. (2)
4. Intercooler pressure.

CALCULATIONS

1. From torgue and speed calculate shaft horsepower (shp)
2. From indicator diagrams determine air horsepower (ahp)
3. Calculate mechanical efficiency $\frac{ahp}{shp}$
4. Calculate mass flow rate (n_A)
5. Calculate volumetric efficiency

   Volumetric efficiency = $\frac{\text{Mass flow rate}}{\text{Mass filling swept volume per minute at } P_o \text{ and } T_o}$
6. Calculate isothermal efficiency where isothermal efficiency = $\frac{\text{isothermal hp}}{\text{Actual shp}}$
7. Calculate theoretically correct intercooler pressure.

   P = $\sqrt{P_o P_R}$;(P_R = receiver pressure)

Indicator diagrams

Include a set for one delivery pressure in your report and from these construct a composite diagram, showing LP and HP diagrams to the same scale correctly placed on P-V axes. The clearance volumes must be taken into account, and also the fact that there are two LP cylinders (the diagram is for only one cylinder).

Graphs

Plot against delivery pressure the following;

(a) shp, ahp, (LP), ahp (HP) and ahp (total)

(b) Mechanical, volumetric and isothermal efficiencies.

(c) Intercooler pressure (actual) and intercooler pressure (Ideal).

OBSERVATIONS **1st Pressure** **2nd Pressure**

Temperatures **MEAN** **MEAN**

A. LP Cylinders

Air in

Air Out

Water in

Water out

B. Intercooler

Air in

Air out

Water in

Water out

C. HP Cylinder

Air in

Air out

Water in

Water out

D. After Cooler

Air in

Air out

Water in

Water out

Orifice Temperature

E. Pressures

Receiver

Intercooler

Orifice Manometer

Barometer

F. Shaft Power

Torgue Arm load

Speed

G. Water Flow Rates

LP Cylinders

Intercooler

HP Cylinder

After Cooler