Vrije Universiteit Brussel

FACULTY OF ENGINEERING

Department of Mechanical Engineering

PISTON ENGINES

Lab Notes

Prof dr. ir. Marc Van Overmeire

Ir Ward De Paepe

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1 Lab 1: The CFR-48

1.1 Introduction

In 1931, CFR-48 engine was developed by a special established committee of motor fabricants and fuel producers. The goal of this committee, commissioned in 1928, was to develop a standard engine for quality testing of fuels, to set up a reference scale for fuels and to develop a standard fuel testing procedure.

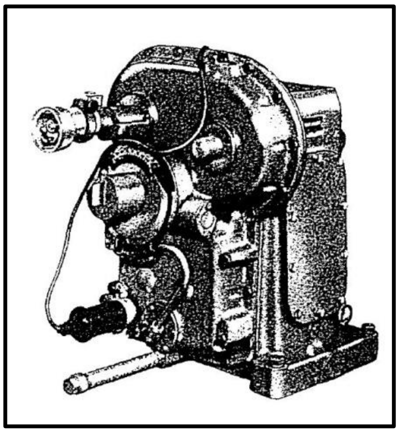


Figure 1.1: The crankcase of the CFR-48

The standard developed engine was the CFR-48. The engine consists of a base model, in fact nothing more than a crankcase, equipped with different cylinder blocks for the different standard test. The crankcase (see Figure 1.1) is a heavy box-shaped structure with removable side doors for easy access. The crankshaft is very heavy; it consists of one crank, counter weights and overlap with the crankpin. The crankshaft is supported by two wide bearings. The gearbox is outside the case. One can choose between two half speed shafts and two full speed shafts. The balancing occurs partly by the counterweight of the crankshaft and partly by a counterweight, rotating in the opposite direction underneath the crankcase. The function of the former is to compensate the fluctuating masses and the latter to compensate the rotating part.

To allow for an adjustable compression ratio, the cylinder head and body are movable with respect to the cylinder block. The adjustments are done manually or by a small engine. By suspending the shaft of the tumbler by a bearer, which can rotate in two points, the valve system will adjust itself, in order to keep the valve tolerance constant. The first point is connected to the crankcase, while the latter one is connected to the moving cylinder block, as can be seen on Figure 1.2. The height difference between the lowest and the highest position is 1 inch. A gauge is installed to measure the pressure ratio. The gauge measures the distance between the cylinder head and block and calculates the compression ratio. During the lab tests however, the compression ratio remains constant.

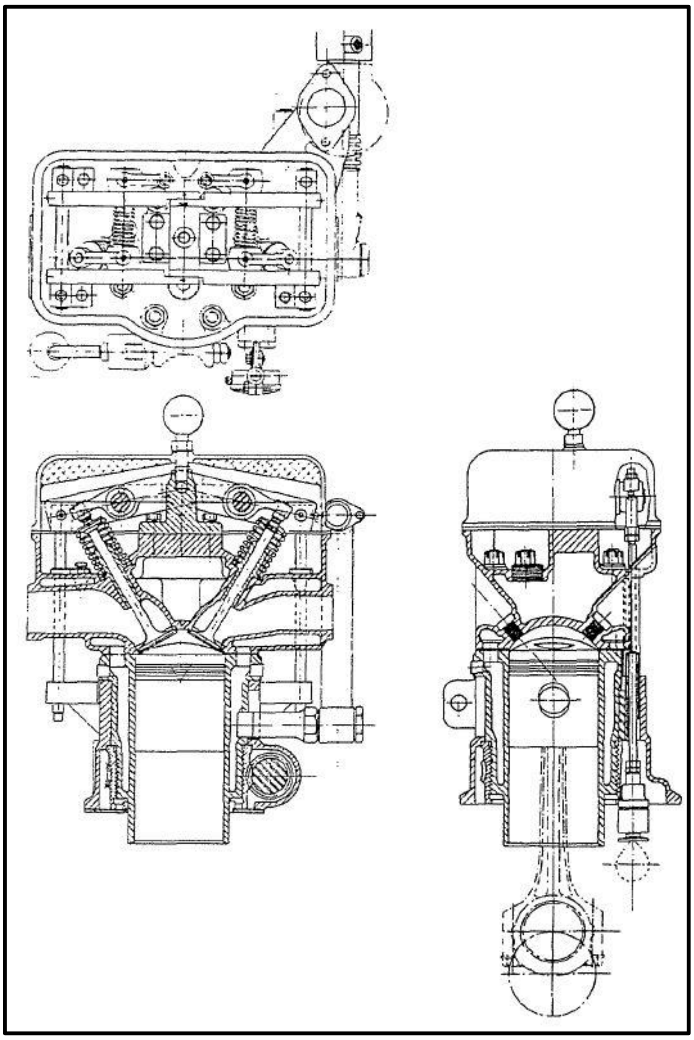


Figure 1.2: Mechanical variable compression ratio.

For the determination of the octane number, the cylinder block with a flat cylinder head and a flat, cast iron piston, with five rings (two oil scraping rings and three sealing rings), is used. The top side of the inlet valve (the upwind side) is provided with a guide ring, in order to prevent vortices. A different design is the one with a hemispherical cylinder head, a lighter piston with three rings (RDH-model Removable Dome Head) and a normal inlet valve. The compression ratio for these systems can be change from 4:1 to 18:1. The classic engine with an aluminium piston instead of a cast iron piston is used for LPG and aircraft fuel testing. For the determination of the cetane number, a piston with five rings is used, but the cylinder head is equipped with an injection system and a combustion chamber, adjustable in size, with high vortex formation (Figure 1.3). The compression ratio here can be changed from 7:1 to 28:1. The engine is also equipped with an ignition delay and measuring system.

There is a primary and secondary water circuit for the cooling of the engine. The primary system is closed and consists of an expansion vessel and a condenser (Figure 1.4). The steam from the boiling water in the expansion vessel is cooled by the secondary cooling water in the condenser. Through natural circulation, it is possible to maintain the temperature of the cooling water at 100°C.

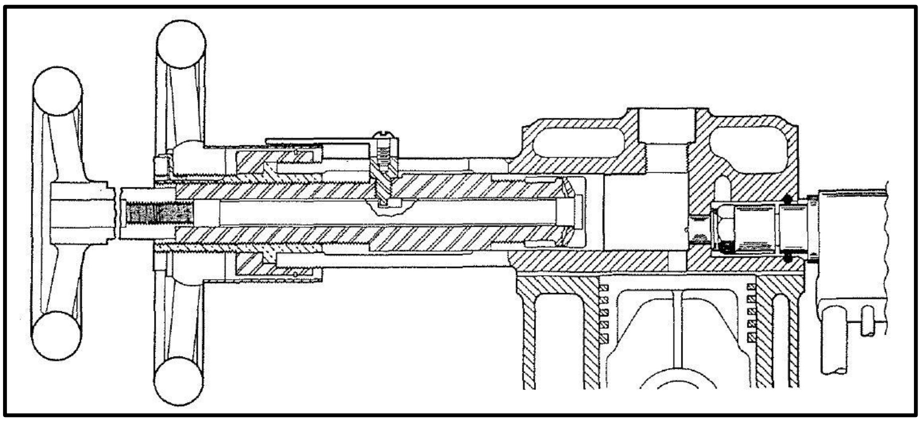


Figure 1.3: Equipment for the determination of the cetane number.

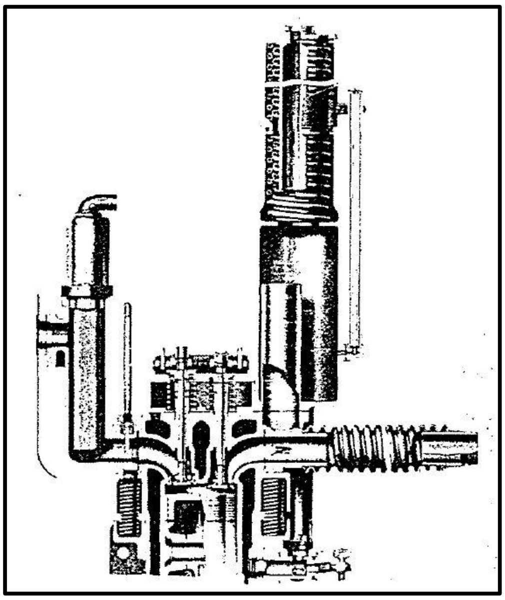


Figure 1.4: The cooling system.

The main characteristics of the RDH-engine in the lab are:

- Compression ratio : adjustable from 4:1 to 18:1,
- Bore : 96.84 mm
- Stroke : 92.08 mm
- Maximal ration speed : 3500 rpm

1.2 Settings

The CFR is an ideal didactic and research engine, because of the one cylinder and the fact that a number of parameters can be changed independent of each other. So one can change the air and fuel flow completely independent of each other. So it is possible to investigate the influence of the air-flue ratio on the engine's performance. Furthermore it is also possible to change manually the ignition time (or the injection time for diesel engines). As mentioned before, it is also possible to change the compression ratio over a wide range, which is very important for fundamental research in piston engines.

The spark plug will ignite before the piston has reached the upper death point during the compression stroke. This ignition advance is expressed in degrees the crankshaft still has to rotate between the ignition point and the upper death point.

Ignition advance is necessary, because the flam front, which starts from the electrodes of the spark plug, needs a limited time to reach the piston surface and to apply force on the crankshaft. The speed of the flame front lies between 10 and 37 m/s. The fuel efficiency is maximal when the flam front reaches the piston surface directly after the upper death point.

The optimal ignition advance is function of the ration speed and the load of the engine, because the air-fuel ratio and the filling rate vary when the load varies. The ignition advance therefore must be adjustable.

Finally, other parameters also have their influence on the combustion of the fuel:

- Knock resistance of the fuel (octane number)
- Inlet air temperature
- Relative humidity of the air
- Air pressure
- Pressure ratio
- State of the engine (wear, losses…)

Cars are equipped with sensors and a microprocessor in order to measure these parameters and to change the ignition advance if necessary.

Industrial petrol engines always run at the same constant conditions, which makes an automatic ignition advance controller not necessary.

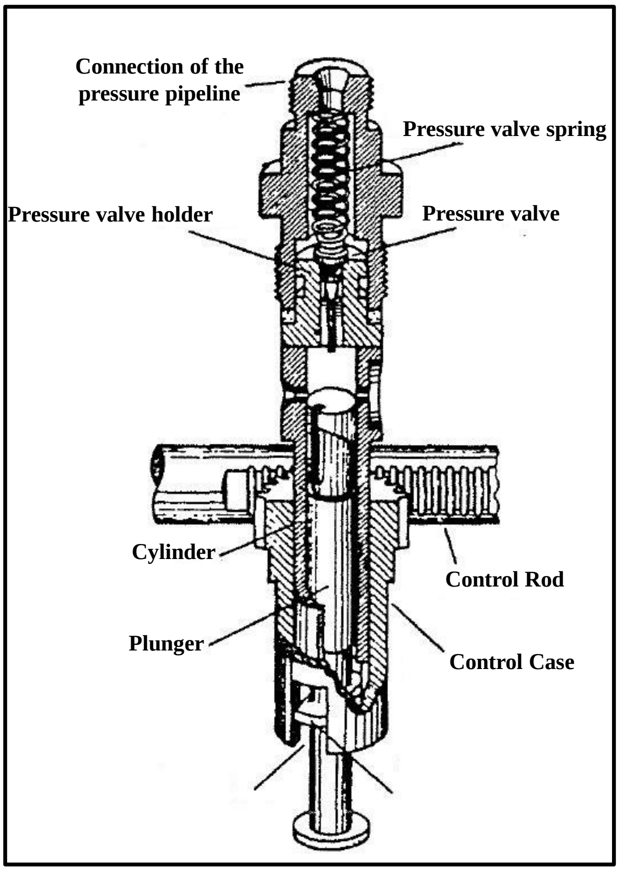


Figure 1.5: The injection pump.

The air flow can be changed manually and independent through a throttle before the inlet manifold.

The position of the throttle will not influence the fuel flow, because the fuel flow is controlled separately by a Bosch injection system. The constant fuel flow at a constant opening position of the injection system is the main advantage of this system. The pressurised gasoline is sprayed into the combustion chamber, which gives a better fuel factor than a carburettor, which results in a lower specific fuel consumption.

The principle of the injection pump is depicted on Figure 1.5. When the position of the fuel lever is changed, the rack profile will move. This will rotate the plunger around his longitudinal axis. Because of the specific profile of the opening in the plunger, the volume of the stroke will be enlarged or reduced, so more or less fuel will be injected. The actual stroke of the plunger remains the same. The position of the plunger and the air valve will determine the fuel factor. Inside the engine of a car, both are regulated together, depending on the asked power. For the CFR in the laboratory, both can be controlled manually and independently.

The theoretic air-fuel ratio for a complete combustion is approximate 1 kg fuel for 14.7 kg of air. A complete combustion however is never achieved in practice; the air-fuel ratio is varied between 0.8 and 1.1 in order to get the best torque or the lowest fuel consumption.

1.3 The load

In order to be able to test the engine, a load has to be applied on to the engine. The motor shaft is connected with a Foucault brake so it is possible to absorb the produced. The brake consists out of a massive disk with stationary coils on both sides of this disk to provide an electromagnetic field in the direction, parallel to the rotation shaft, perpendicular on the massive disk. Once the shaft starts to rotate, induction currents will be provoked inside the disk through the changing magnetic field, seen by the disk. The induction currents directions and corresponding magnetic field, are in such a way that it will counteract on the rotation of the shaft. The braking force will increase with increasing magnetic flux through the disk or with increasing current through the coils. The induction current, rose inside the disk, is called Foucault currents or eddy current and it will heat up the disk. The produced heat will be evacuated using cooling water. So eventually, it is the cooling water that will absorb the energy/power produced by the engine.

The rotations speed of the CFR-engine is controlled by the currents of the coils of the brake. The generator, providing these currents, consists of a PID-controller, which allows working at constant rotation speed. The rotation speed can be set by the potentiometer on the generator.

1.4 The measurements

1.4.1 The fuel flow

By measuring the time necessary to consume a certain amount of fuel (20g), it is possible to measure the fuel flow. This type of measurement is called a gravimetrical measurement.

1.4.2 The air flow

The air flow can be measured by taking the pressure loss over a measuring flange in the inlet manifold. The inlet air mass flow is given by:

$$Q_l = kS\sqrt{2\rho\Delta p}$$

Where:

- Q_l = the inlet air mass flow, in kg/s
- K = the pressure loss coefficient, depending on the geometry of the flange = 0.604
- S = the surface of the flange at the venturi (ϕ = 24.0 mm), in m²
- Δp = the pressure loss in the measure flange, in Pa. The pressure loss is expressed as a height difference on a manometer, Δh.
- ρ = the density of the inlet air, in kg/m³

The gas constant is 287 J/kgK.

Do not forget to measure temperature and atmospheric pressure in the lab.

1.4.3 The engine torque

The actual torque on the shaft is captured with a strain gauge torque meter. This meter consists out of a calibrated shaft, which is deformed by the engine torque. The strain gauge is attached to this shaft; under a 45° angle with the axis (maximal torsional stress is applied in this direction). The strain gauge rotates along with the axis, so the signal has to be transported, using two cupper rings. The signal is shown digital.

The torque is measured every second. The CFR-engine is a 1-cylindrical engine, which results in a varying torque during the 4-stroke cycle, even though the shaft is connected to a flywheel. So the measured torque will not be constant at constant rotation speed, hence it will be oscillating around an average value. The torque is expressed in Nm.

1.4.4 The temperatures

The temperature in the lab is measured using a Mercury-in-glass thermometer, installed at the inlet air manifold.

Four thermocouples are mounted upon the engine, in order to measure the temperature of the in- and outgoing cooling water, the motor oil in the crankcase and the exhaust gasses. The displayed temperature is expressed in °C.

1.4.5 The CO- and UHC-concentration

An infrared absorption measuring devices is used to sample the concentration of CO and Unburned Hydro Carbons (UHC) concentration in the exhaust air. The infrared rays are absorbed through the large number of gas molecules and every molecule has its own, typical wave length range. Once an infrared ray, with limited wave length, goes through a gas sample, a specific wave length will be absorbed by the gas molecules, resulting in a lower intensity for that wave length. As the concentration of the gas molecules increases, the intensity of the infrared light will decrease.

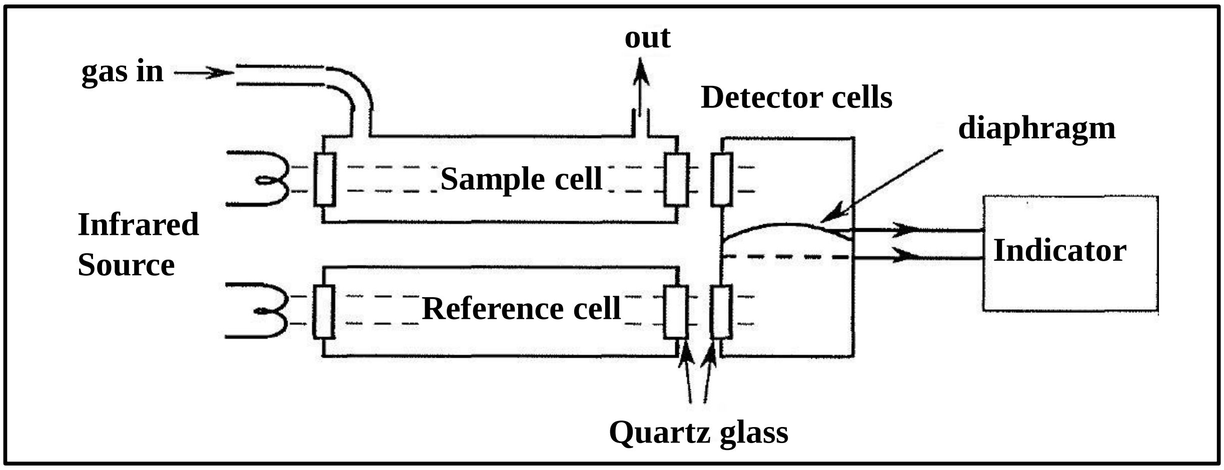


Figure 1.6: NDIR gas concentration measurement.

Figure 1.6 shows how the previous explained process is used in the “Non-Dispersive InfraRed gas Analyser”. The detector cell and sample cell are filled with gas that needs to be analysed, while the reference cell is filled with air. Radiation energy is absorbed in the detector cells, which will increase the temperature and pressure. The gas in the sample cell however also contains CO (or UHC), so part of the energy is already absorbed in the sample cell, leading to less energy absorption in the upper detector cell, compared to the lower detector cell. This will leads to a pressure difference between the cells, resulting in a deflection of the diaphragm. This deflection is captured by the indicator and transformed into a concentration. Reference gasses with well-known concentration are used for the calibration of the meter. This calibration needs to be performed on a regular basis.

The presence of CO_2 has a disturbing effect on the measurement of the CO concentration, because both gasses absorb radiation in the range of 4.4 micron. By using a filter cell, filled with CO_2, between the radiation source and the reference and sample cell, the present CO_2 in the exhaust gas can not cause any further absorption.

The formation of soot and condensation of the water on the quartz glass can also disturb the measurement. In order to prevent this, the gas samples are filtered and the piping and sample cell are heated.

N-hexane is used as reference gas in the detector cell by the Exhaust Performance Analyser model U-912-I (Sun), to determine the UHC concentration.

The gasses have to travel a long distance between the combustion chamber and the gas analyser, so when performing measurements, one should take the time delay into account.

1.4.6 The pressure

The same device as for the exhaust gas composition can be used to measure the pressure in the inlet manifold.

1.5 Assignments

When any problem occurs, ask assistance of qualified persons.

Smoking is not allowed in the lab.

A fire extinguisher is within reach.

The processing of the measurement is done by an EXCEL spread sheet. The emphasis in this lab is on the discussion of the results. For the result, the derivation of every formula is asked as well as the determination of the gross error on the result.

The adjustable parameters are:

- Airflow, by the air valve in the inlet manifold,
- Fuel flow, by the throttle on the injection pump,
- Rotation speed, by the potentiometer. One must handle this with care, because the PID controller can react fast, resulting in a peak in the brake current, so the safety interferes and cuts the current. The voltage of the coil will be cut so there is no more ignition and the engine will stop,
- Ignition advance, by turning manually the casing (the ignition advance is made visual on the fly wheel, by means of a stroboscope).

1.5.1 Influence of the rotation speed

This test is performed for rotation speeds going from 600 rpm till 1400 rpm, in steps of 200 rpm and always with $\lambda=1$. The position of the throttle is set once for every speed. This allows the investigation of the effect of the gas flow speed (turbulence has an influence on the quality of the mixture) and the inertia forces.

The following formula gives the correlation between Δt, Δh (in m) and the air-fuel ratio and the atmospheric conditions (p_0 in mm Hg)

$$127\left(\frac{\lambda}{\Delta t}\right)^2 = \Delta h \frac{p_0}{T_0}$$

Prove this and use this formula to set the throttle.

The ignition advance needs to be changed in order to obtain maximal torque.

Measure for each rotation speed the following parameters: Δt; Δh; M, the mean engine torque; ΔM, the variation of M; α, the ignition advance; T_{uit}, temperature of the exhaust gasses, $[CO_2]$, $[UHC]$.

Insert these values in the spread sheet and print the made diagrams.

1.5.2 Influence of the air-fuel ratio

The experiment is carried out at n = 1200 rpm and λ varies between 0.6 and 1.2 in steps of 0.1. The fuel factor is controlled by changing the fuel throttle. This is done as follows: change the air valve back to the value from test 1 at λ = 1. Measure the consumption time of the fuel and calculated the air factor. Read the value at the fuel throttle. Change the throttle to get more fuel, read the value and measure Δt. Do this again for less fuel. Three values of throttle with according λ's are known, so estimate the intermediate throttle values. Calculate the according water height for the wanted λ using the previous formula.

Change before every measurement the ignition advance in order to obtain a maximal, stable torque.

Measure at each λ the following parameters: Δt; Δh; M; ΔM; α; T_{uit}; $[CO_2]$; $[UHC]$

1.5.3 Influence of the ignition advance

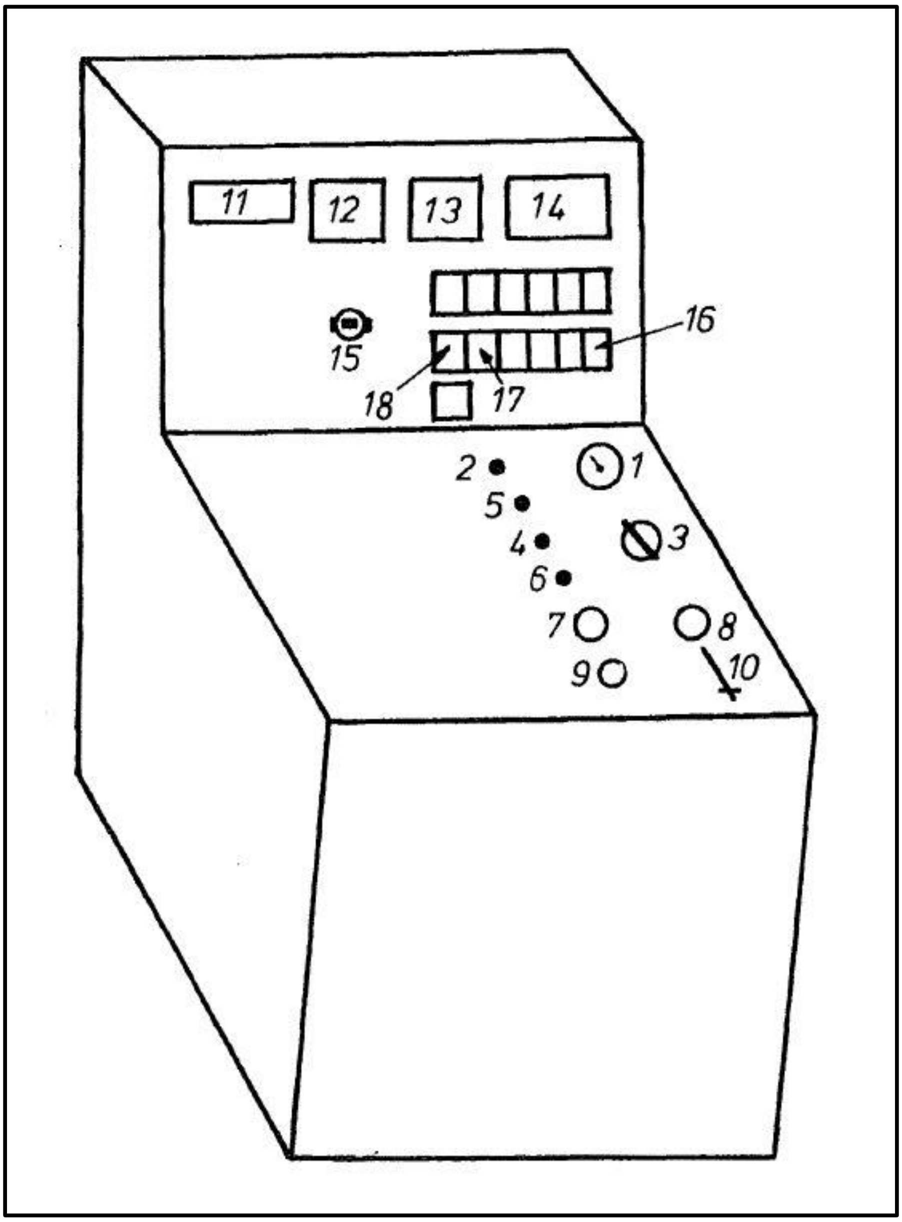
This test is performed at 1000 rpm and λ = 1. Start the measurements at 0°kh and increase the ignition advance with steps of 5°kh until detonation.

Measure at each ignition advance the following parameters: M; ΔM; α; T_{uit}; $[CO_2]$; $[UHC]$

1.5.4 Influence of the load

This test is also performed at 1000 rpm and λ = 1. By changing the lever (5), the load can be changed. Measure the fuel flow and adjust the air flow in order to get λ = 1. Change at each point the ignition advance in order to reach maximal torque.

Measure at each λ the following parameters: M; ΔM; α; T_{uit}; $[CO_2]$; $[UHC]$ and Δp, the pressure in the inlet manifold.



1. Gasoline level indicator

3. Contact lock and key

12. Indication of the current of the coils of the Foucault brake

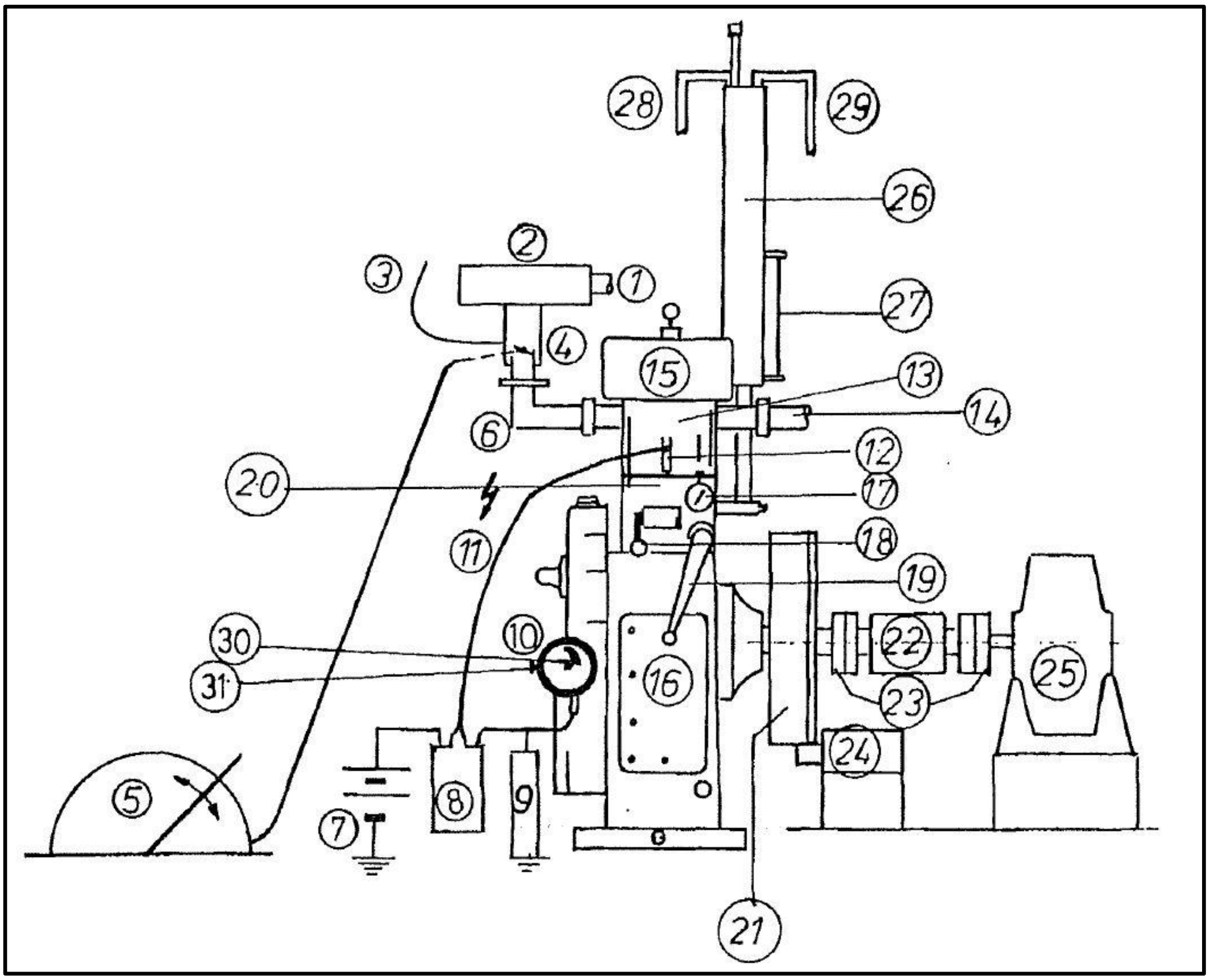
13. over speed safety

14. Rotation speed indication

15. Potentiometer for the load regulation

The other switches are not important for the lab

Figure 1.7: Control panel



1. Air inlet
2. Air filter
3. Injection pump
4. Air valve
5. Fuel throttle
6. Injection in inlet manifold
7. Battery
8. Coil
9. Transistor ignition
10. Distributer
11. High voltage cable
12. Spark plug
13. Cylinder head
14. Exhaust
15. Valve head
16. Crank shaft
17. Gauge
18. Lock for compression control
19. Compression control
20. Cylinder side
21. Flywheel
22. Torque meter
23. Coupling
24. Start engine
25. Foucault brake
26. Heat exchanger for cooling
27. Cooling water level indicator
28. Inlet secondary cooling circuit
29. Exhaust secondary cooling circuit
30. Distributor contact
31. Screw for distributor

Figure 1.8: Measuring setup

2 Lab 2: SF

2.1 Introduction

For the lab setup and the working of the control panel, we refer to chapter 1 and 3 of the manual of the SF-7100.

2.2 Assignments

This lab is divided into two sessions, one experiment on a diesel engine and a second one on a gasoline engine. Measure twice the

- Performance curves of the engines at different throttle positions.
- Acceleration characteristics of the engine at full throttle and different degrees of acceleration.

3 Lab 3: The ignition mechanism

3.1 Introduction

The combustion in a gasoline engine is always started with a spark. This spark arises between the electrodes of the spark plug. The necessary energy to make this spark is delivered by the battery, after it is recharged by the dynamo.

The battery voltage is 12V and sometimes 24V. This is by far not enough to get a spark between the electrodes of the spark plug. The function of the ignition system is to transform the voltage from the battery to the necessary voltage to obtain a spark and lead this voltage to the right spark plug. Depending on the engine type, a voltage between 5 and 20 kV is necessary to get a breakdown. This voltage is called the ionization voltage. The ionization voltage makes the space between the electrodes conductive, so the spark can jump from one electrode to the other. The temperature of this spark is a few 1000 degrees Celsius. This high temperature will ignite the mixture in the combustion chamber. The combustion will continue afterwards automatically. The only condition however is that the mixture has the correct composition, i.e. it is between his flammability limits. A good contact between the mixture and the spark is made by the specific setup of the spark plug in the combustion chamber, the spark time and the flow of the gasses. Finally, the spark needs to contain a limited amount of energy, namely the ignition energy. Below this energy, the mixture will not ignite. A high flammable mixture needs ignition energy of maximal 0.1 mJ. The necessary energy however increases when there is more or less fuel in the mixture, or when the temperature is low in the combustion chamber, i.e. at a cold start-up. In order to be sure to get ignition in all conditions, the energy used for the spark is between 50 and 70 mJ.

The point of ignition is chosen in such a way that knocking of the engine is avoided over its complete load range. The constructors also have to take into account the different load, the fuel consumption and the exhaust gasses.

3.1.1 The conventional coil ignition

The cycle is obtained by mechanical contact points. High demands are asked, mechanical as well as electrical. For a four stroke, 6-cylinder engine, working at 6000 rpm, they have to conduct 18,000 times per minute a current of some amperes. The energy source for this current is the coil. The coil collects the magnetic energy and transforms it in a high voltage shock at the time of ignition. The process is based on the induction principle. Figure 3.1 shows a schematically view of the conventional coil ignition and Figure 3.2 shows the real parts of the system.

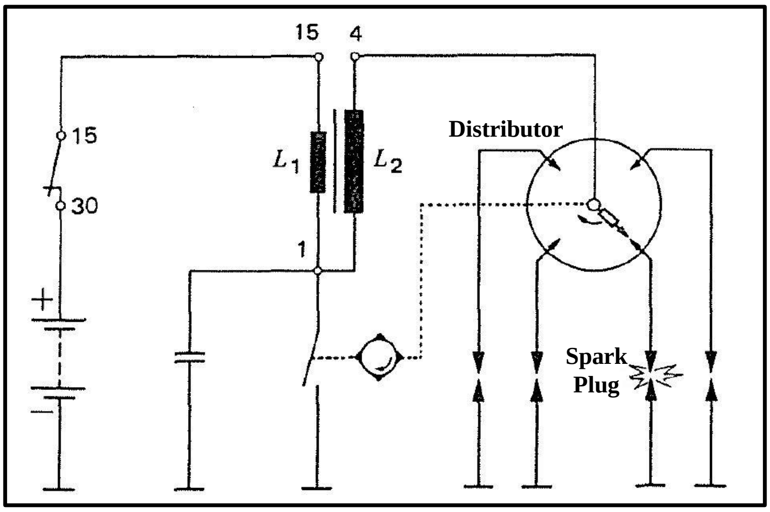


Figure 3.1: The conventional coil ignition system

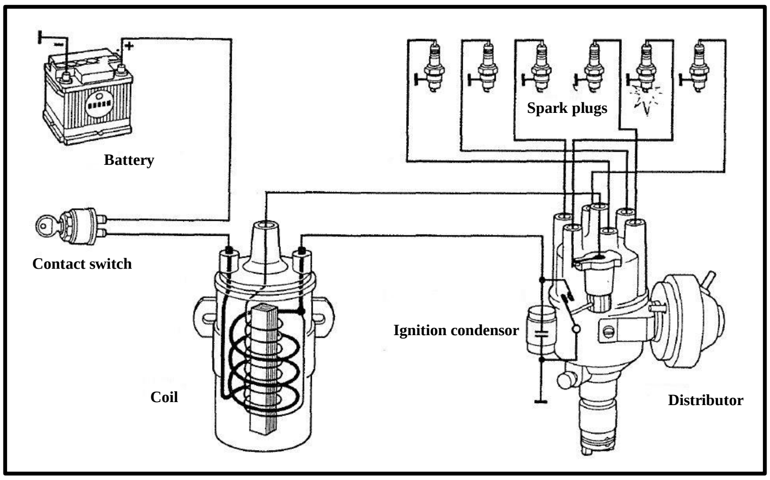


Figure 3.2: Parts of the conventional spark ignition system

The coil consists of two coils, wrapped around each other and an iron core. The primary winding (L1) has less turns of a thicker cupper wire than the secondary winding (L2), which has more turns of a smaller wire. The one end of the primary winding (15) is connected through the contact switch with the positive pole of the battery while the other part (1) is connected with some connection points to the mass. The capacitor is placed parallel with these points. The secondary winding has mutual connection with the primary and the other connection goes through the conductor and the cables of the spark plugs to the central electrode of the spark plugs.

3.1.2 Working principle

Once the connection points of the primary circuit are closed, a current start to run through this circuit, which increases exponentially to its asymptotic value (RL-circuit). A magnetic field is built up by this current. Once the connection points are opened, a higher induction voltage is raised, depending on the time it takes for the magnetic field to disappear. This induction voltage is transformed in the coil to a higher voltage (the transformation ration in the coil is typically 100) in the secondary circuit, which raises a voltage peak between 20 and 30 kV.

Figure 3.3 shows what happens when no spark breaks through occurs. Because of the capacitor, it is possible to dissipate the energy in the primary circuit, which now consists of a RLC-circuit. After the damping of the voltage, the voltage over the capacitor equals the battery voltage. Once the contact close again, the capacitor is shorted and his voltage drop to zero. This phenomenon is reflected in the secondary circuit by a transformed voltage drop. This will damp to zero because of the start of a new cycle in the primary circuit.

Figure 3.4 shows the cycle with a spark, i.e. the secondary circuit is loaded. The conductor and the breaker cam are on the same axis, so the contacts will open at the same moment the rotor electrode is at the contact point of a spark plug cable. Once the contact is open and the voltage reaches the ionization voltage (typically 15 kV), the gas between the spark plug electrodes becomes conduction and a spark can occur. The current running through the spark lowers the voltage till the spark voltage, which is a few kV. Around 30 µs have passed since the opening of the contact points. At that moment, there is no longer enough magnetic energy to support the spark. From that point, the same voltage profile as in the unloaded conditions repeats.

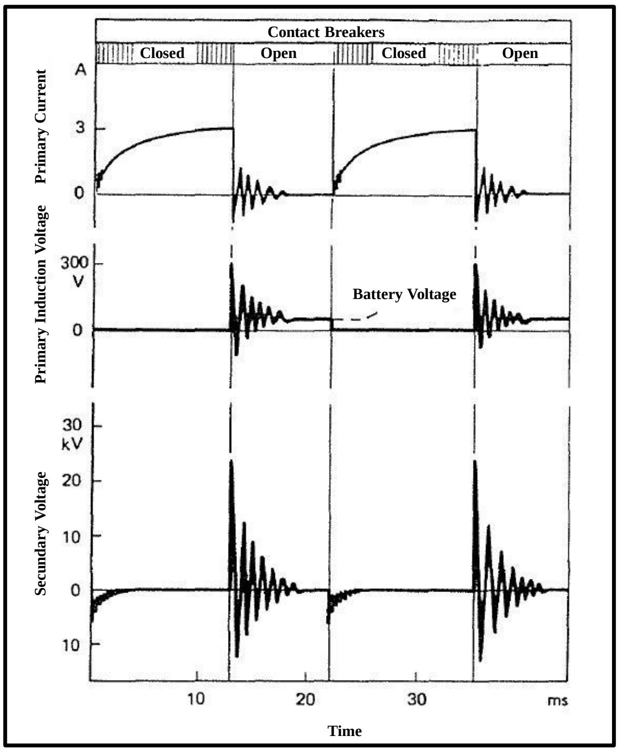


Figure 3.3: Voltge and current image without spark

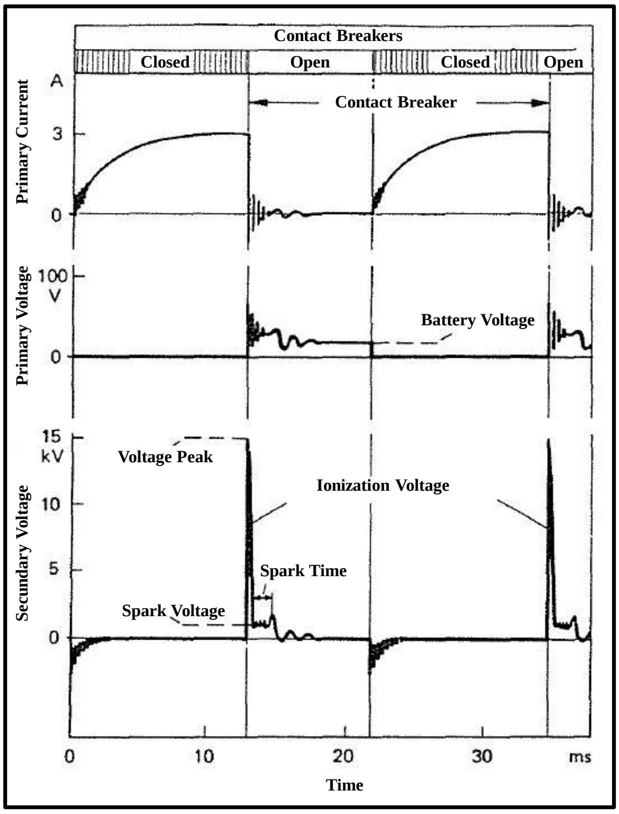


Figure 3.4: Voltage and current image with spark.

Figure 3.5 gives a zoom of the spark part of the previous images. The spark time does not only depend on the available amount of energy, but also on the movement of the mixture. It can be seen that at higher rotations speed, the spark is broken several times and rebuilds itself due to the strong turbulence. Every time the spark is rebuilt, energy is lost, resulting in a decreasing spark time.

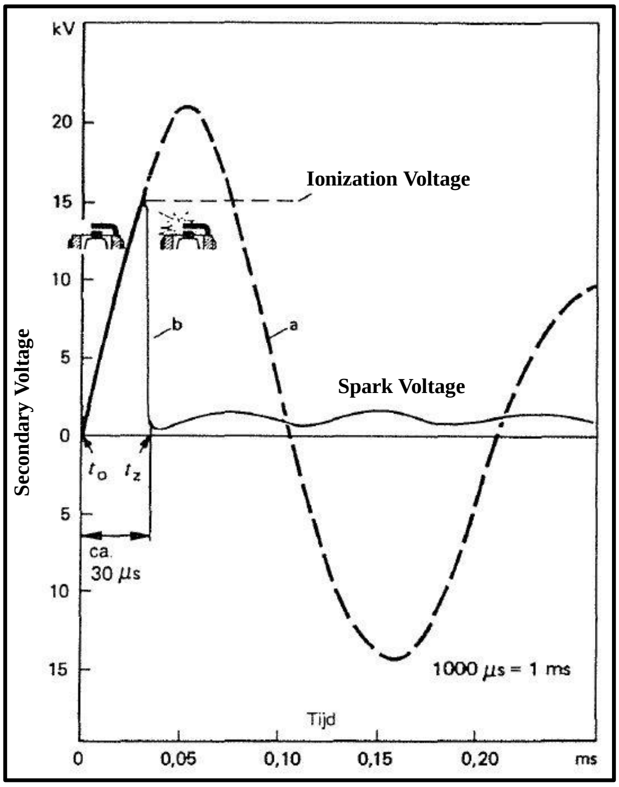


Figure 3.5: Voltage image (a) without and (b) with spark

(t_0 = opening time and t_z= ignition time)

The secondary winding had the opposite polarity of the primary, resulting in a negative central electrode after the voltage peak, which is the result of the opening of the contact point. In this case, the electrons will go from the central electrode of the spark plug to the other electrode, which results in a higher quality spark. The quality of the spark is also negatively affected by a parasitic parallel resistance in the circuit, like condensation, dirt, unburned fuel on the isolation of the spark plug, and a capacitor load due to long coil and spark plug cables.

3.1.3 Function of the capacitor

When the primary circuit is cut, the induction voltage is 300 to 400 V, and this will lead to a spark between the contacts, if no precautions are taken. This will lead to a loss of energy, more wear of the contact points and a higher temperature, what leads to a higher resistance of the primary circuit, resulting in less stored energy. To prevent this, a capacitor is placed parallel to the contact point, which will catch the induction current shock when the contact points open. The capacitor voltage builds up till the induction voltage and this needs a certain time. Meanwhile, the contact points opened more, so it is impossible to get a spark, because the spark voltage is at that moment higher than the induced voltage. This works fine for one rotation speed. In practice however, an engine works at different rotation speeds. The charging of the capacitor, a low speeds (till 3000 sparks per minute) however is too fast, so there is still a spark between the contact points, which is called the opening spark. The contact points of cars in the city have to be replaced more often, due to the different driving.

3.1.4 Influence of the rotation speed on the spark

So far, two effects have already been mentioned. At high speed, the spark time is decreased due to the strong turbulence in the combustion chamber. At low speed, the wear of the contact points is higher.

The time to build up the magnetic field becomes smaller at increasing rotation speed. At a certain speed, the time is too short for the primary circuit to reach its asymptotic value. This results in a reduced high voltage, which is the maximal secondary voltage without spark (see Figure 3.3) and the available spark energy (so also the spark time). Figure 3.6 shows these effects (a) and also shows the effect of bad shielded cables (b) and a parasitair parallel resistance due to the fouling of the spark plug (c).

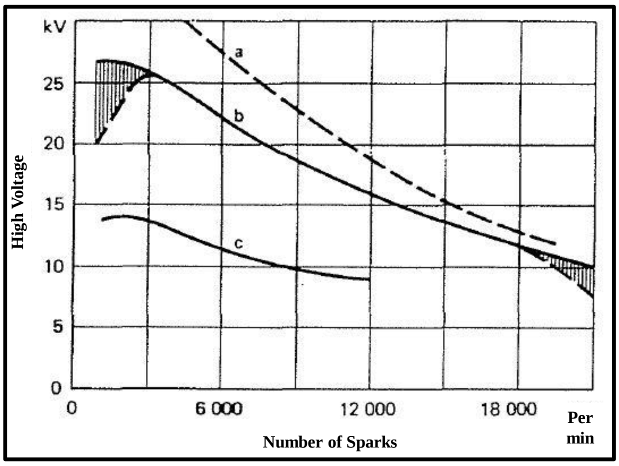


Figure 3.6: the available high voltage in function of the frequency of the sparks

Figure 3.6 shows also the influence of the opening spark, which occurs till 3000 sparks per minute. At 18000 sparks per minute, the available high voltage starts to decrease, as a result of the bouncing contact points.

As a conclusion, one can say that the engine will stop running due to a missing ignition, due to a high parasitair resistance in the secondary circuit, the bouncing of the contact point at high rotations speed and the sparks on the contact points at low rotation speed.

3.1.5 The technical aspects

Figure 3.7 shows the composition of the coil. The iron core is easy to recognize. It consists of bare-shaped blades. Around the core are the secondary windings, consisting out of 15000 till 30000 turns of very fine cupper wire. The primary winding lay around the secondary and has a hundred bigger cupper turns. The turn ratio lies in between 50 and 150. The direction of the turns is in such a way that high voltage pulls is negative compared to the mass. The coil is subjected to very high standard in electric isolation, losses and vibration resistance.

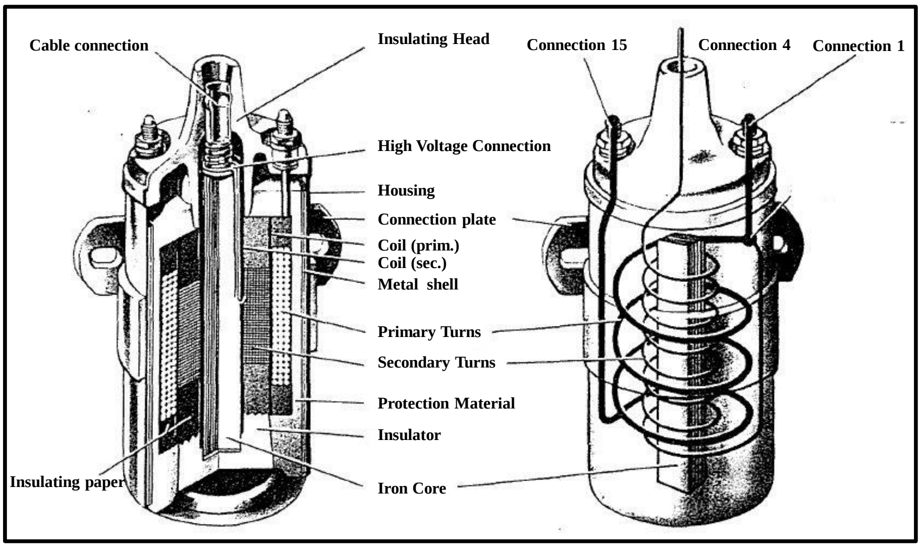


Figure 3.7: The coil

Figure 3.8 shows the conductor, the conductor points can be seen as switches, controlled by a cam. The cam breaker (2) is powered by an axis, which is connected to the cam axis. A sliding block (8) of the breaking hammer (6) moves over the rotating cam breaker. This opens and closes the primary circuit. The number of cams equals the number of cylinders.

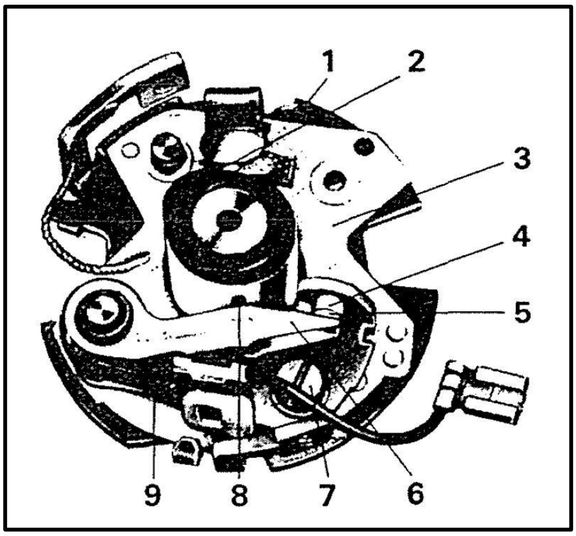


Figure 3.8: Single breaker point setup of a one cylinder engine

A critical parameter in the ignition system is the dwell. This is the angle of the breaker axis, between the closing and the breaking of the contact points. This angle will determine the accessible time to charge the magnetic field. The bigger the distance between the contact points, the bigger the dwell. A smaller distance will lead to a more efficient ignition progress at low rotation speed, which results in a higher opening speed, leading to less opening sparks. However, the smaller distance results in a worse ignition progress at high rotation speed. A smaller distance results in a better ignition progress at high rotation speed, however at low rpm, more opening sparks will occur. The best solution is a compromise between both. Figure 3.9 gives an illustration of a large distance (b) and a small distance (c).

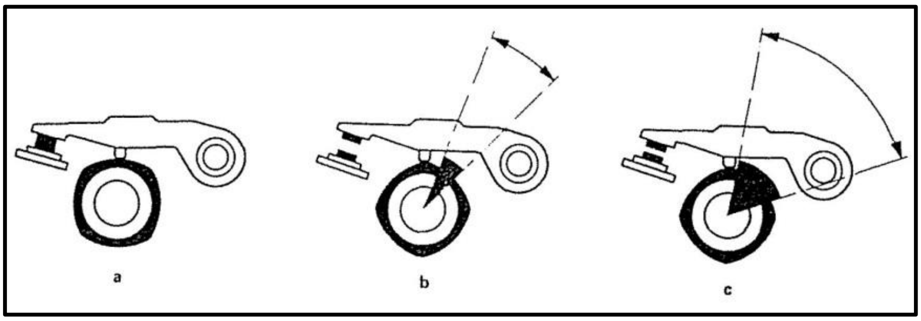


Figure 3.9: schematic view of the contact points

The contact breaker is heavily charged, mechanically as well as electrical. The points are made of tungsten, because of its high hardness and high melting point. A good contact breaker can switch at 500V and a current of 5 A, 250,000 times per minute. The wear especially takes place at the contact points, the sliding block and the cam.

In addition, the conductor is sealed with the conductor hat, which contains the connection, namely the cables to the coil and to the spark plugs (Figure 3.10). The conductor rotor is directly connected to the cam breaker. The high voltage is conducted through a carbon brush. The spark will jump from rotor to the fixed contact points, inside the hat, at the moment the rotor passes by. The distance between the rotor electrode and the fixed contact point is 0.5 mm. This kind of transmission however uses energy, but it is contactless, so there is no wear.

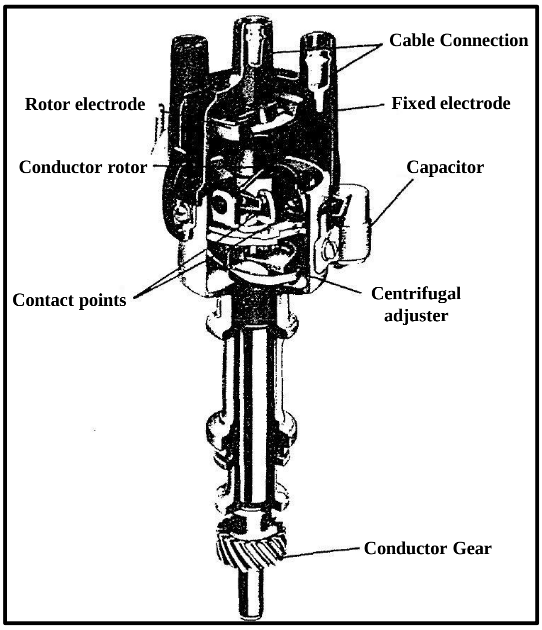


Figure 3.10: cut plot of the contact breaker.

The electrical process in the hat of the conductor produces NO_X and ozone. These toxic and aggressive gasses are carried away through the ventilation. When there is not enough ventilation, the metal parts will start to corrode (contact points, breaker cam, sliding block) and the isolation material will start to degrade.

The ignition advance mechanism is also located in the housing of the conductor and the breaker. Their operation is very simple and needs no explanation. Figure 3.11 and Figure 3.12

show two variants of the centrifugal ignition advance systems. Figure 3.13 depicts how the vacuum system works

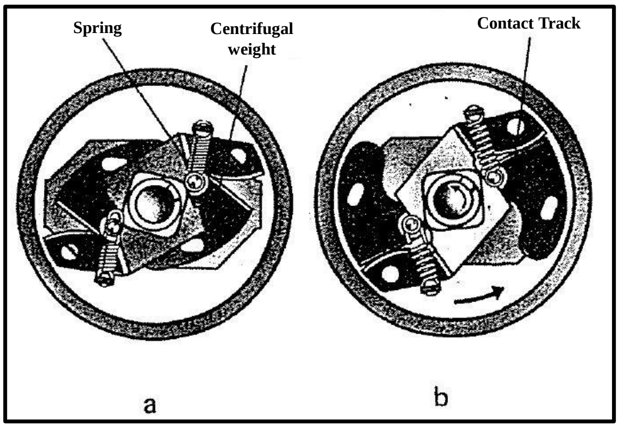


Figure 3.11: Ignition advance mechanism at rest (a) and in operation (b)

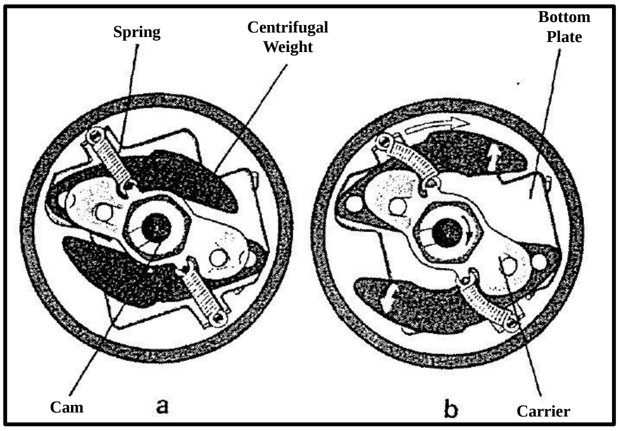


Figure 3.12: Ignition advance mechanism at rest (a) and in operation (b)

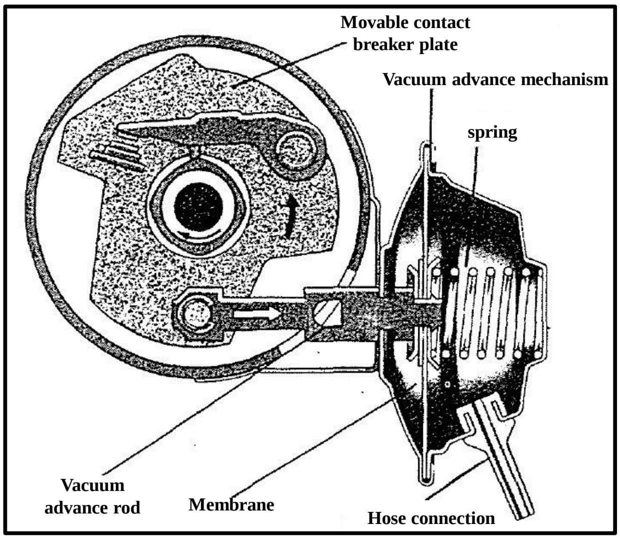


Figure 3.13: Ignition advance mechanism (vacuum) at rest (a) and in operation (b)

3.2 The equipment

For the experiments, a sun scope ss-400-2 will be used. The operation of this scope will be explained by the assistant during the lab.

3.3 Assignments

a) Study the circuit and find the primary and secondary circuit
   Study the simulator, using the volt and ohm meter of the Sun-tester, by measuring point to point. Determine the values of the different resistance in the circuit.
b) Study the voltage profile in the primary and secondary circuit.
c) Measure the available voltage at the coil. Detach the high voltage cable between the coil and the distributor. Read the voltage on the oscilloscope.
   Measure the available voltage at the spark plugs by detaching one of the cables of the spark plugs.
d) Isolation of the secondary circuit:
   Detach a cable of a spark plug, and keep the picture in mind. Bring the cable then closer to the mass until you see a spark and watch again the picture on the oscilloscope. The negative oscillations are missing. This is the picture you get once there is a leak in the secondary circuit.
e) Cross spark
   In the distributor, there is a metal connection between two contact points of the spark plug cables. If one of these cables is detached, the picture on the oscilloscope will not change, explain. When detaching both of the cables, the pictures changes. Explain.
f) Next to the 8 ‘good’ spark plugs, 2 ‘adapted’ spark plugs are mounted on the panel. The two electrodes are too far from each other on the first spark plug and on the other one, the two electrodes are connected two each other. Bring these spark plugs in the circuit and explain what you see.
g) Capacitor mode
   Change the switch in order to get the parallel resistor in the circuit and change the potentiometer. Explain what you see. Hold the switch of the series resistor and study what you see.
h) Dwell measurements
   Change the dwell or contact angle of the distributor and study what you see.

Do not touch the spark plug!