

# ICE Laboratory

## Energy Balance

### Objective

To know what is the benefit of Engine Energy Balance and how we made engine test and knowing its performance.

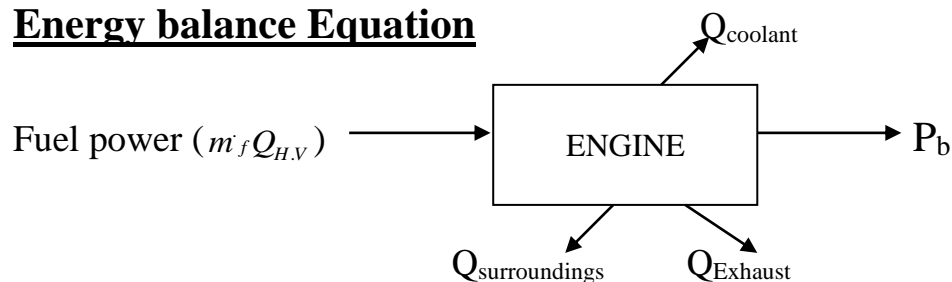
### Discussion

- Why do we need to do Engine Energy Balance?
- How can we test the engine performance?
- What are the tools that used in testing the engine?

### Engine Energy Balance

There are many reasons to perform an energy balance study on an engine. **The knowledge of how the energy is lost will help in finding means to improve the performance of the engine in terms of efficiency and power output.** This seems to be the main reason behind most energy studies performed on engines. By improving the efficiency of the engine, the result is a higher percentage of the fuel's energy getting converted into power output. This is noticed as improved performance. Although the goal of understanding engine operation to improve efficiency is common, there are many different reasons an energy balance study helps to reach this goal. Energy balances studies help characterize the impact a change has on the overall system. Once the impact is identified by the energy balance, one can attempt to either maximize or oppose its use due to the benefits and drawbacks. These changes include variations in fuel, physical changes to engine design, or adjustments of engine settings.

### Energy balance Equation



$$m_f Q_{H.V} = P_b + Q_{coolant} + Q_{Exhaust} + Q_{surrounding}$$

Where

$m_f$  Is mass flow rate of the fuel (Kg/s)

$Q_{H.V}$  Is the heating value of the fuel (KJ/Kg)

$P_b$  Is the Brake Power of the engine (KW)

- $Q_{coolant}$  Is the heat loss to the coolant (KW)  
 $Q_{Exhaust}$  Is the heat loss from the exhaust (KW)  
 $Q_{surrounding}$  Is a loss to surroundings that cannot be calculated (friction, oil, radiation)

Now we will take each term and explain how to measure it

## Fuel Power

This is the Power which we take from the Fuel. This power is resulted from the chemical reaction of fuel which gives us the heat and explosion we need. We calculate it from the product of mass flow rate multiplied by the Heating value of the fuel .

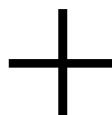
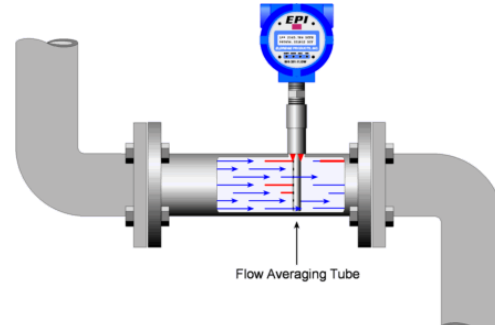
$$\text{Fuel Power} = \dot{m}_f * Q_{H.V}$$

$Q_{H.V}$  (diesel) = **43.1** MJ/Kg

Density of diesel fuel = **830** Kg/m<sup>3</sup>

## How to measure Fuel Power

Fuel flow rates ( $\dot{m}_f$ ) were measured with flow meters or else by measuring the volume of fuel consumed and the specific time of consumption.



## **Brake Power ( $P_b$ )**

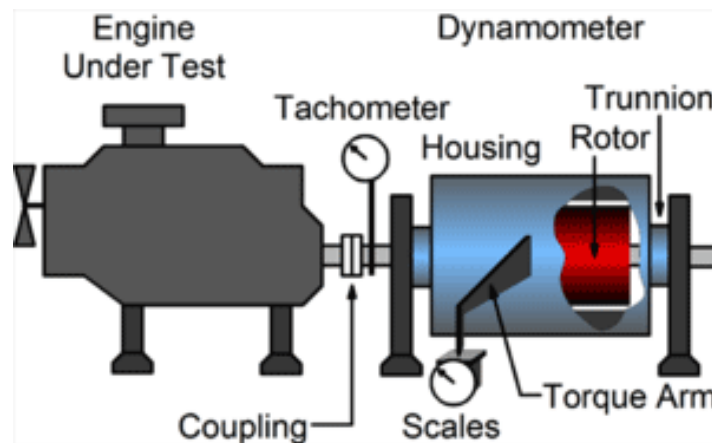
Brake power is the measure of an engine's power without the loss in power caused by the gearbox, alternator, differential, water pump, and other auxiliary components. We get it from the product of the torque multiplied by the RPM of the Engine

$$\text{Brake Power} = \tau_b \times \omega$$

$$\text{BP(KW)} = \text{load(lb)} * \text{N(rpm)} * 0.746 / 2800$$

### **How to measure Brake Power**

In order to measure **the brake Torque ( $\tau_b$ )** of the engines **dynamometers** were used. Hydraulic brake dynamometers were used in most cases examined, however, it should be noted that other dynamometers such as water brake, fan brake, prony brake, eddy current, direct current, or electric motor/generator.



We can measure **engine speed ( $\omega$ )** by using **tachometers**



## Coolant Losses ( $Q_{\text{Coolant}}$ )

This is the heat loss to the coolant. We may name it losses but actually we need to do it to reduce the temperature of the engine. To measure the energy transferred through conduction of engine components, the losses to the coolant, are calculated by:

$$\text{Coolant Losses} = m_c \times c_p \times (T_{c,o} - T_{c,i})$$

$$m_c = 0.0533292 * \text{sqrt}(h)$$

Where

$m_c$  is the coolant mass flow rate (Kg/s)

$c_p$  is the specific heat at constant pressure (for water = 4.186 KJ/Kg.k)

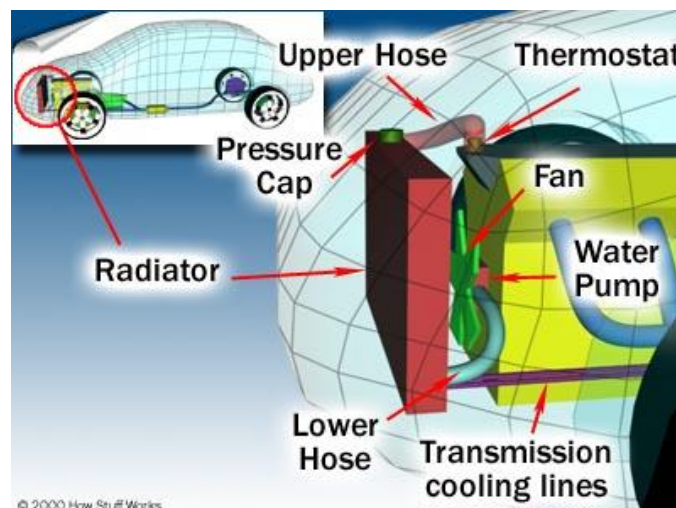
$T_{c,o}$  is outlet coolant temperature

$T_{c,i}$  is inlet coolant temperature

$h$  is manometer reading in ( mm )

## How to measure Coolant Losses ( $Q_c$ )

Heat loss to the engine coolant was usually measured by finding the difference in coolant temperature at the engine's inlet and outlet.



## Exhaust Losses ( $Q_{\text{Exhaust}}$ )

It is the heat that is released from the exhaust system which contains heat that can be used in any other process in the car. The losses through the exhaust were determined by measuring the air and fuel flow rates, and determining the exhaust gas temperature

$$\text{Exhaust Losses} = m_e \times c_{p_{ex}} \times (T_{ex} - T_{amb})$$

$$m_e = m_{air} + m_{fuel}$$

$$m_{air} = \rho_{air} \times C_d \times A_o \times \sqrt{2 \times g \times h_w \times \rho_w / \rho_{air}}$$

Where

$m_e$  is the Exhaust mass flow rate

$C_{p_{ex}}$  is the specific heat at constant pressure (if not given assume it = 1.13 KJ/Kg.k)

$T_{ex}$  is exhaust temperature

$T_{amb}$  is ambient temperature

$C_d$  is coefficient of discharge ( 0.658 )

$\rho_{air}$  assume 1.23 kg/m<sup>3</sup>

$A_o$  is area of orifice ( value is 0.001353 m<sup>2</sup> )

### How to measure Exhaust Losses ( $Q_E$ )

For measuring losses to the exhaust, finding the mass flow rate of the exhaust by direct measurement or from adding **the air and fuel flow rates** into the engine, then maximum heat can be found from cooling the exhaust to ambient temperature.

**Air flow rates** were measured with either some kind of flow meter or by a pressure change (manometer) in a flow element.



### **Losses to surrounding ( $Q_{surrounding}$ )**

This term we can not measure it but we can calculate it from the difference of the fuel power and the other losses. This type of losses may go to the oil or friction or by radiation from the cylinder block or anything we cannot calculate easily

## **Energy balance for the Engine**

We will make a variable load test for the engine. All sensors are connected to the engine and all indicators are working.

### **Procedure:**

1. Start the engine
2. Open the throttle valve until the speed reach 1000 rpm
3. Wait while the engine is running until you reach steady state
4. Read all the data shown in the table from the indicators
5. Repeat the same procedures with load varying between (0, 5, 10, 15, and 20)lb

<b>NO.</b>	<b>Speed (RPM)</b>	<b>Load W (lb)</b>	<b><math>h_{cw}</math></b>	<b><math>T_{c,i}</math></b>	<b><math>T_{c,o}</math></b>	<b><math>h_{w\_air}</math></b>	<b><math>T_{ex}</math></b>	<b><math>V_{fuel}</math></b>	<b>time</b>
1									
2									
3									
4									
5									

### **Requirements**

1. Fill the table and calculate all types of losses
2. Draw relationship between the types of Energy and Load on the engine  
(Load on X-axis ,, Energy on Y-axis)
  - a. Each energy vs load in a separate graph (5 graphs)
  - b. All energies on 1 graph vs load
3. Calculate the percentage of each type of losses to the fuel power at a given load ( say 10 lb)
4. Report about one type of dynamometer.

	FUEL ENERGY				DYNO.		COOLING LOSSES					EXHAUST LOSSES					
N (RPM)	Vol.	time	$m_f^*$	F.P	W	B.P	h	$m_{cw}^*$	T <sub>in</sub>	T <sub>out</sub>	Q <sub>cool</sub>	h	$m_{air}^*$	$m_{ex}^*$	T <sub>ex</sub>	Q <sub>exh.</sub>	Q <sub>surr</sub>