GOVERNED ENGINE TESTS

OBJECTIVE:

During this laboratory period you will run an engine test similar to the power-take off portion of a Nebraska Tractor Test. Certain additional information not normally included in a Nebraska Test will also be developed. Parameters of interest are engine torque, horsepower, RPM, fuel and air consumption.

1. To observe the manner in which a governed engine reacts to changes in load.
2. To determine horsepower and torque at various loading of a governed engine.
3. To observe the effect of load on fuel consumption efficiency.
4. To observe volumetric efficiencies under varying loads.

PROCEDURE:

A. The class should organize so as to have all members participate in some phase of the test: operation, data collection, or data analysis.

B. Before starting the engine, confirm that the dynamometer control knobs and switches are in the following positions:

Controller power sw. -	"off"
Dynamometer power sw. -	"off"
Performance monitor sw. -	"load"
Load control pot -	"fully counter-clockwise"*
Load switcher:	
Man./Ext. -	Out (Man.)
Torque/Current -	Out (Torque)
RPM control pot -	"fully clockwise"*
RPM switches:	
RPM/Load -	Out (RPM)
Man./Ext. -	Out (Man.)

* Be certain controls are unlocked before attempting settings.

With the exception of the controller and dynamometer power switch and RPM control pot, all switches are in a position for completing the test.

C. Start the engine and run until thoroughly warmed. To hasten warming:
1. Engage dynamometer with engine clutch.
2. Open throttle to about 1500 rpm.
3. Turn on controller power and dynamometer power switches (yellow lamps on). Red "excitation" lamp may glow.
4. Place the RPM/Load switch in the “OUT” (Load) position. Turn load pot clockwise to load engine slightly. **DO NOT OVERLOAD!**
5. Leave the load on until engine operating temperature reaches approximately 160° F. Turn load pot fully anti-clockwise to unload the engine. Place the RPM/Load switch in the “IN” (RPM) position. .

D. When engine is warm, you are ready to begin a test.

1. Be certain load knob is returned to full counter-clockwise position.
2. Open throttle all the way (w.o.t.). Record values of engine load (lbs), RPM, fuel flow (gph), and air flow (cfm) on the accompanying data sheet. These values represent the first run under load due to the method of connecting engine dynamometer and controls.

Using the controller load pot, and beginning at the high engine speed and ending at approximately 1100 rpm, slowly decrease the load (cw pot rotation) on the engine in appropriate steps to obtain at least 10 sets of readings. The first five of these readings should be between highest and rated speed. (Rated speed is that speed at which the governor has the throttle plate in the carburetor -- or injection delivery valve in the case of diesels -- in the fully open position.) The remaining five runs should be equally spaced over the difference of the rated speed and approximately 1100 rpm.

Repeat steps 2 & 3 with throttle settings of 80% of w.o.t. and 60% of w.o.t.

5. When load tests are complete, remove load (cw rpm pot rotation) from the dynamometer and reduce the engine speed to approximately 750 rpm (idle). Note and record the value of air consumption.
6. De-clutch the dynamometer. Let idle for one minute. Shut off engine.

EQUIPMENT: Governed engine, dynamometer which indicates load and speed, fuel and air flow measurements equipment and a stopwatch.

THEORY:

$$Hp = \frac{2\pi FRN}{33000} = \frac{TN}{5252}$$

Where Hp = horsepower
T = torque, ft-lbs
F = net dynamometer load, lbs.
R = length of dynamometer reaction arm, ft.
(.885 ft or 27 cm for the lab dynamometer)
N = dynamometer speed, rpm
2π = constant, number of radians in 360° of rotation
33000 = constant, 1 Hp = 33000 ft-lb/min

In metric units, tractor power is expressed in kilowatts (kW) where:

$$kW = \frac{2\pi FRN}{60}$$

F = dynamometer force, kiloNewtons (kN)
R = reaction arm length, meters (m)
N = dynamometer speed, rpm
2π = number of radians in 360° of rotation
60 = sec/min

One measure of fuel efficiency is **specific fuel consumption**, the quantity of fuel required per unit of work done. This is expressed as **kg of fuel/(kW-hr)** or **lbs of fuel/(hp-hr)**, and is calculated by dividing the fuel consumption, kg/hr or lbs/hr by the power.

Another measure of fuel efficiency is **thermal efficiency**, T.E.

$$T.E. = \frac{power\ output}{heat\ power\ input} = \frac{kW}{(kilojoules/kg)(kg/hr)(1hr/3600\sec)} \quad OR \quad = \frac{(Hp)(2545Btu/hp-hr)}{(lb/hr)(Btu/lb)}$$

Mixtures of air and fuel will burn only when they are mixed in correct proportion. This proportion of air and fuel is known as the "air-fuel ratio" and is determined on a weight (or mass) basis. The ratio can be determined by measuring air and fuel inputs for a given operating condition and substituting the proper values in the equation:

$$A/F = \frac{lb\ air}{lb\ fuel} \quad OR \quad \frac{kg\ air}{kg\ fuel}$$

If measurements are on the rate basis, i.e. lb/min or kg/min, then one may substitute as follows:

$$A/F = \frac{lb\ air/\min}{lb\ fuel/\min} \quad OR \quad \frac{kg\ air/\min}{kg\ fuel/\min}$$

Volumetric efficiency (V.E.) represents the percentage of piston displacement filled with gasses during say, an intake stroke, and there is a distinct relation between it and the engine cylinder's mean effective pressure (M.E.P.) and hence, power output. V.E. is the ratio of actual volume to the theoretical volume of intake.

$$V.E. = \frac{Measured\ cfm}{Theoretical\ cfm}$$

Note the calculation of theoretical air flow requires a knowledge of the number of engine revolutions per intake strokes. For a 4 str. cycle, there are 2 revolutions per intake stroke

Finally, the effective pressure resulting from combustion can be determined. These represent average working pressures throughout the power stroke and are called **mean effective pressures**. These can be determined for 4-stroke engines, from the M.E.P. equation:

$$P_i = \frac{p_{imep} L A_p N_e n}{60*10^6 (rc)} = \frac{p_{imep} D_e N_e}{60*10^3 (rc)} \qquad D_e = \frac{A_p L n}{1000}$$

P_i = Indicated Power kW
p_i = Indicated Mean Effective Pressure kPa
D_e = Engine Displacement L
N_e = Crankshaft speed rpm
rc = Crankshaft rev per engine cycle (1 or 2)
A_p = top area of piston (cm^2) = $\pi d^2 / 4$
L = Stroke Lenght, cm
n = number of engine cylinders

$$P_i = \frac{p_{imep} L A_p N_e n}{33*10^3 (rc)} = \frac{p_{imep} (D_e / 12) N_e}{33*10^3 (rc)} \qquad D_e = A_p (L) n$$

P_i = Indicated Power Hp
p_i = Indicated Mean Effective Pressure psi
D_e = Engine Displacement ($inches^3$)
N_e = Crankshaft speed rpm
rc = Crankshaft rev per engine cycle (1 or 2)
A_p = top area of piston ($inches^2$) = $\pi d^2 / 4$
L = Stroke Lenght, inches
n = number of engine cylinders

REPORT:

1. For each set of data taken calculate:
   a) Engine Brake Power and Torque.
   b) Brake Specific fuel consumption,
   c) Brake Thermal efficiency (%)
   d) Brake Mean effective pressures (psi, kPa)
   e) Air-fuel ratio (mass air/mass fuel)
   f) Volumetric efficiency for each run, including idle speed; where
      V.E. = Act. Vol. of air intake / Theor. Vol. of intake

   Show one complete set of sample calculations. Include your data sheets with your report.

2. Plot engine power, torque and spec. fuel consumption vs. engine rpm. Use good graphing techniques. Be sure to include a title block with graph title, tractor model, your name, class, and date. Show location of governed range, load control range, high idle speed, rated engine speed, and rated power on plots. (No load, or high idle, speed may be obtained by extrapolating the right hand portion of the hp and torque curves of Step 1 to an intersection with the abscissa, for the WOT test)

3. Do max. power and torque occur at the same point - why or why not?

4. Does torque continue to rise somewhat in the load control range? What aspect of engine performance does this characteristic describe?

5. Discuss your results. Explain the relationship between power, torque and spec. fuel consumption.
   Explain why power and torque curves are shaped the way they are.
   Why are the curve shapes different in the governed range compared to the load control range?
   What engine rpm would you select for a 45 hp output?
   Discuss the relationship between vol. eff., engine rpm and the governor (fuel per injection). Hint: The optimum valve timing is different at different engine speeds and turbocharger boost depends on exhaust temperature and pressure.

6. Why does the specific fuel consumption increase rapidly in the governed range?

7. Plot torque and mass of fuel per injection cycle versus rpm. Comment on the shape of the curves. How would you increase the torque reserve of an engine.

<u>Possibly useful conversion factors</u>

1 lb ≈ 4.4482 newtons	1 in = 2.54 cm
1 atm ≈ 101.3 kPa ≈ 14.696 psi	1 gal = 231 in^3

Name ________________ Date: ____________

OBSERVED DATA - DYNAMOMETER TESTS

Engine:

Make & No. Cyls. ______________________

Bore & Stroke(in,cm) 4.2" 5" (106mm, 127mm)

Calculated Displacement (in^3,L) ____________

Fuel Properties:

Type Diesel

Weight 6.9 lbs/gal (823 kg/m^3)

Heat Content 19350 BTU/lb, (45000 KJ/kg)

Dynamometer

Brake Arm Length 0.885ft (27 cm)

Air Properties:

Barometer __________mm HG

Temp. ______________

Rel. Hum. ____________%

Sp. Vol. 13.9 ft^3/lb, 0.868 m^3/lb)

Run #	Engine Speed (rpm)	Dynamometer Load (lbs)	Fuel Flow (lb/min)	Airflow meter (cm H_2O)	Air Flow (Cfm)= 55 *R	Air Flow (lb/min)
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2						
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