UNITED NATIONS ESCAP Economic and Social Commission for Asia and the Pacific CSAM

CAMTC

TRAINING ON ANTAM STANDARD CODE
For TESTING OF KNAPSACK MISTERS CUM DUSTERS

Theory 5: Engine Performance - The engine test cell

Test Code Section IV(2) and D-6

2nd Training of Trainers on ANTAM Codes
16 - 28 October2016, Nanjing China

ANTAM Asian and Pacific Network for Testing Agricultural Machinery

The Test Engineer

… "the test Engineer concerned with any aspect of engine testing,… must have at his fingertips a wide and ever-broadening range of knowledge and skills….. A particular problem he must face is that, while he is required to master ever more advanced experimental techniques – such areas as emissions analysis and engine calibration come to mind – he cannot afford to neglect any of the more traditional aspects of the subject. Such basic matters as the mounting of the engine, coupling it to the dynamometer and leading away the exhaust gases can give rise to intractable problems, misleading results and even on occasion to disastrous accidents. More than one engineer has been killed as a result of faulty installation of engines on test beds"

-MartyrA.J. and M.A. Plint

MartyrA.J. and M.A. Plint 2007,Engine Testing Theory and Practice Third edition Published by Elsevier Ltd

Caution:

- Traditional SI engines have simple control systems- carburetors and CI engines have pump rack controlled by simple governor.
- The advent of Electronic control units (ECUs)- complex strategy of control by taking signals from the transmission system- control of test conditions out of hands of the test engineer- (Not for present day power tiller)

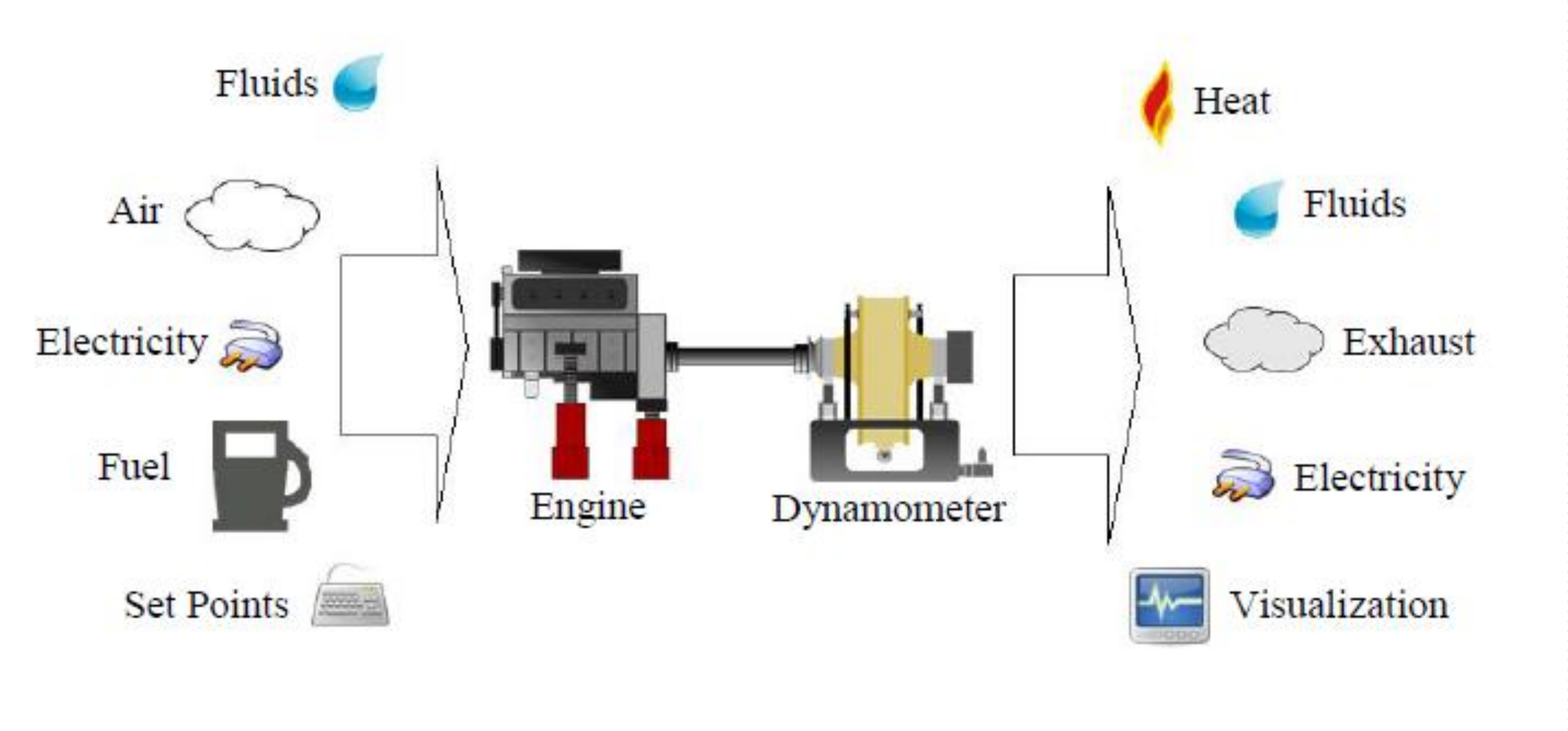
Equivalents and standards

- 1 cal=4.1868 J or 1Kcal=4.1868kJ
- Absolute temperature Kelvin K = Deg Celsius +273.15
- 1Horse power= 745.7 W
- Standard Atmospheric pressure= 1bar=10^5Pa=14.5lbf/in^2
- 1mm of water column=9.81 Pa

Specification of the test facility
(New facility)

- Operational specification:
  - Describing ‘what it is for’, created by the user.
  - Test facility for engine testing of tractors and power tillers are different. Also the tractor PTO dynamometer, axle dynamometer, Power tiller rotary test dynamometer are different in terms of speed, torque, loading and control capabilities.
  - The nature of test are also different.
- Functional specification:
  - Describing ‘what it consists of and where it goes’, created either by the user group or the implementing agency.
- Detailed functional specification:
  - Describing ‘how it all works’ created by the project designer

The thermodynamic model of engine test cell



Anthony Joseph Fountaine 2012 Design of an Engine Test Cell Control System by
Thesis submitted for Degree of Master of Applied Science at the University of Windsor *University of Windsor*

The test cell as a thermodynamic system

IN	OUT
Fuel	
Air- ventilation	Air- Ventilation
Combustion air	Engine Exhaust
Cooling water	Engine Cooling water
	Dynamometer Cooling water
Electricity for services	Electricity from Dynamometer
	Losses through walls and ceiling

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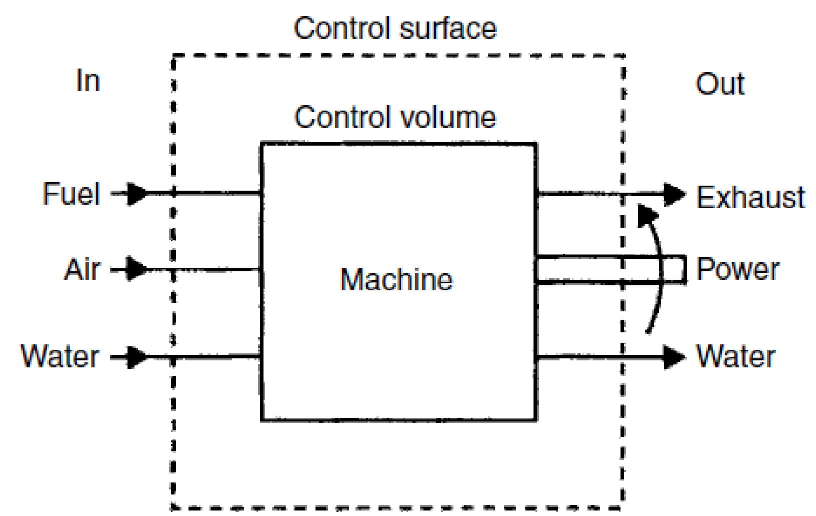

Energy balance of Engine

- Dynamometer 30%
- Exhaust system 30%
- Engine fluids 30 %
- Convection and radiation 10%

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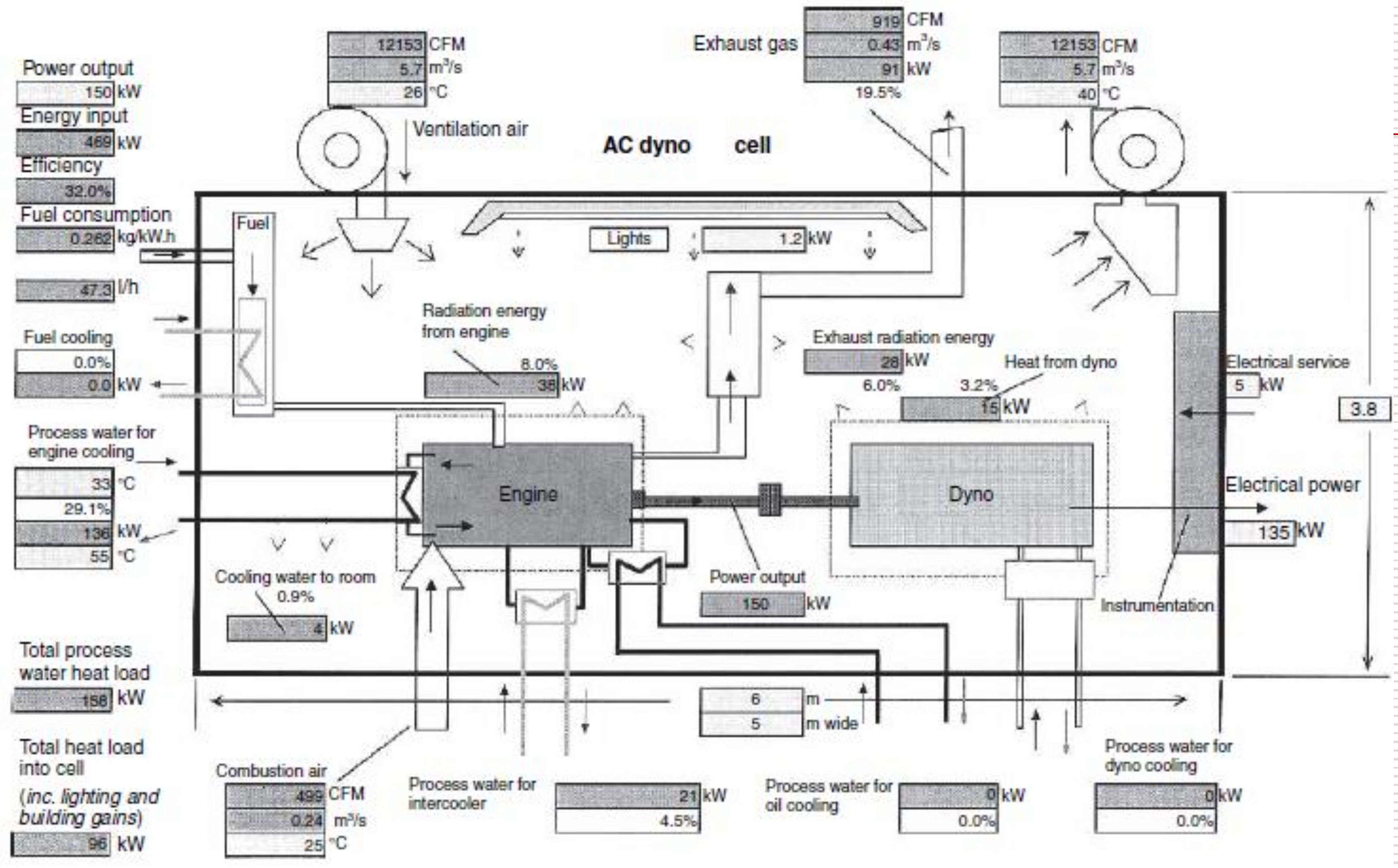
Model of a Engine test cell



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Ventilation requirements of test cell

- The performance and power output of the engine is affected by the condition temperature, pressure and humidity of the intake air.
- The air used by the engine may come from the cell ventilation air or from a treatment unit outside the cell.
- Proper ventilation is required to maintain the quality of intake air
- In a test cell large amounts of power will be generated in a comparatively small space

The heat capacity of cooling air

- The PV elation of air is as follows

$$P_a \times 10^5 = \rho \, R(t_a + 273)$$

Where

$P_a = Atmospheric\ \mathrm{Pr}.\ in\ bar$

$\rho = density\ of\ air\ kg/m^3$

$R = Gas\ Const.\ for\ air = 287\ J/kgK$

$t_a = air\ temperature\ °C$

- Under 25^0C, the density ρ=1.185 kg/m^3

Heat capacity of air

- The Cp value for air=1.01 kJ/kgK
- Then the air flow required to carry away 1kW of energy at 10^0C temperature raise

$$= \frac{1}{1.01 \times 10} = 0.099 kg/s = 0.084 m^3/s = 2.9 ft^3/s$$

- Though the heat is transferred to air by convection, and radiation, It can be assumed that the heat released to air as 40 % of the engine output for water cooled iesel.

Sample calculation

- For a 7.5kW water cooled Diesel
- Heat loss to air @40 % of rated power=3kw
- Air circulation required for 10 deg. Temp raise between inlet and outlet= 8.7 cubic feet/s

- Note if the test is conducted in a open test cell, Only air circulation will be required to maintain the temperature instead of ducted ventilating air.

INSTRUMENTATION FOR ENGINE TEST CELL

Measurement	Principal applications	Method
Time interval	Rotational speed	Tachometer Single impulse trigger Starter ring gear Shaft encoder
Force, quasistatic	Dynamometer torque	Dead weights and Spring balance Hydraulic load cell Load cell Strain Guage tranducer
Force, cyclic	Stress and Bearing load investigation	Strain Guage tranducer Piezoelectric transducer
Pressure, quasistatic	Flow systems; lubricant, fuel, water, pressure charge, exhaust	Liquid monometer Bourdon tube Strain Guage transducer

Pressure Cyclic	In-cylinder, inlet, exhaust	Strain gauge transducer
Flow	events. Fuel injection	Capacitative transducer
	pressure	Piezoelectric transducer
Position	Throtle and other controls	Mechanical linkage and pointer, counter LVDT transducer Shaft encoder Stepper motor
Displacement, cyclic	Valve lift, injection needle lift	Inductive transducer Hall effect transducer Capacitative transducer

Acceleration	Engine balancing, NVH	Strain gauge accelerometer Piezoelectric accelerometer
Temperature	Cooling water, lubricant, inlet air, exhaust in-cylinder, mechanical components	Liquid-in-glass Vapour pressure Liquid-in-steel Thermocouple PRT Thermistor Electrical resistance Optical pyrometer Suction pyrometer

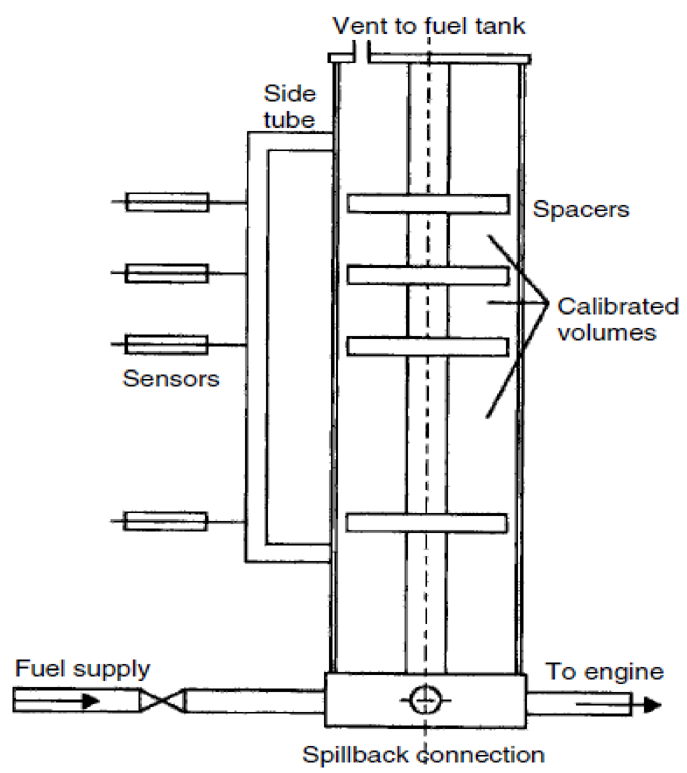
Instrumentation for fuel measurement

- For all liquid fuel consumption measurement, it is critical to control fuel temperature within the metered system as far as is possible.
- Modern cells have a closely integrated temperature control and measurement system.
- The condition of the fuel returned from the engine can cause significant problems as it may return at
  - Pulsing pressure,
  - Considerably warmer than the control temperature
  - Containing vapour bubbles.

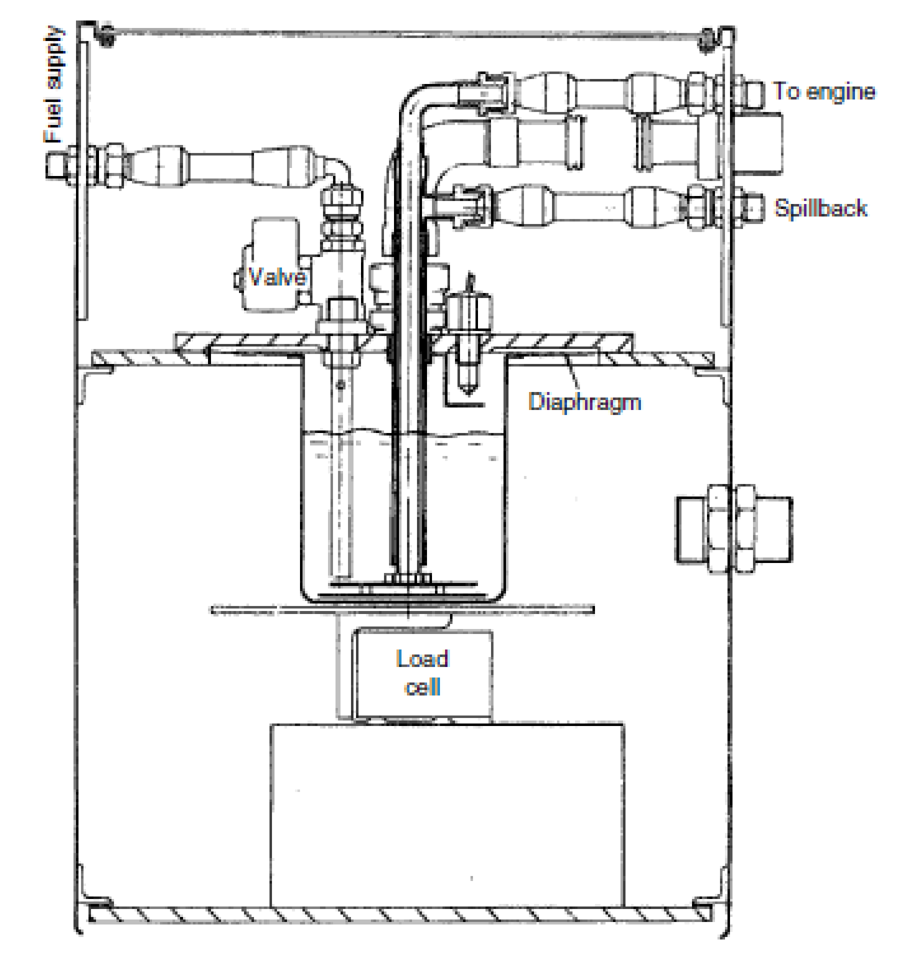
Types of fuel flow meter

- Volumetric gauges, which measure the number of engine revolutions taken to consume a known volume of fuel
  - Either from containment of known volume
  - Or as measurement of flow through a measuring device.
- Gravimetric gauges, which measure the number of engine revolutions taken to consume a known mass of fuel.

Volumetric gauge with optical sensing



Gravimetric fuel measurement



The air box method of measuring air consumption

- The methods of measuring air consumption involve drawing the air through orifice and measuring the pressure drop across the orifice.
- The pressure drop is to be within 125mm H_2O, for considering flow as incompressible.

Flow through Orifice

$$U = \sqrt{\frac{2\Delta p}{\rho}}$$

$$and\ \ Flow\ Q = U \times A \times C_d$$

$$where$$

$$Q = \ flow\ m^3 / s$$

$$U = velocity\ \ m/s$$

$$A = Area\ m^2$$

$$and\ C_d = Disch\arg\ coeff\ . = 0.6$$

Role of the test Engineer

- There must be an adequate understanding of the relevant theory.
- The necessary apparatus and instrumentation must be assembled and, if necessary, designed and constructed.
- The experimental program must itself be designed, with due regard to the levels of accuracy required and with an awareness of possible pitfalls, misleading results and undetected sources of error.
- The test program is executed, the engineer keeping a close watch on progress.
- The test data are reduced and presented in a suitable form to the ‘customer’ and to the level of accuracy required.
- The findings are summarized and related to the questions the program was intended to answer.

Variations in test results

- The assessment of an engine's performance by measuring using different test beds may not yield identical results.
- Very substantial changes in engine performance can arise from changes in atmospheric (and hence in combustion air) conditions.
- Engine power output is highly sensitive to variations in fuel, lubricating oil and cooling water
- Finally, it is unlikely that a set of test cells will be totally identical: apparently
- Small differences in such factors as the layout of the ventilation air louvres and in the exhaust system can have a significant effect on performance
- BS 5514, standard lists the 'permissible deviation' in engine torque as measured repeatedly during a single test run on a single test bed as 2 per cent.