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 6: Engine Performance - Dynamometry Test

Code Section IV(2) and D-6

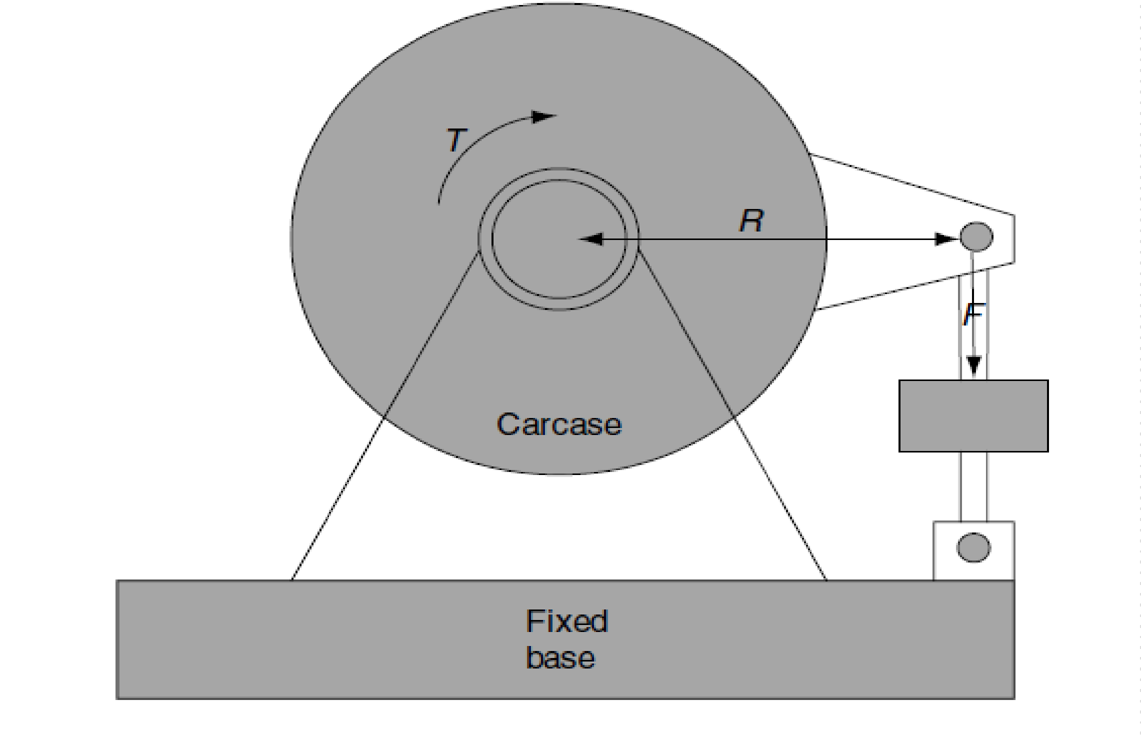
2nd Training of Trainers on ANTAM Codes
16 - 28 October2016, Nanjing China

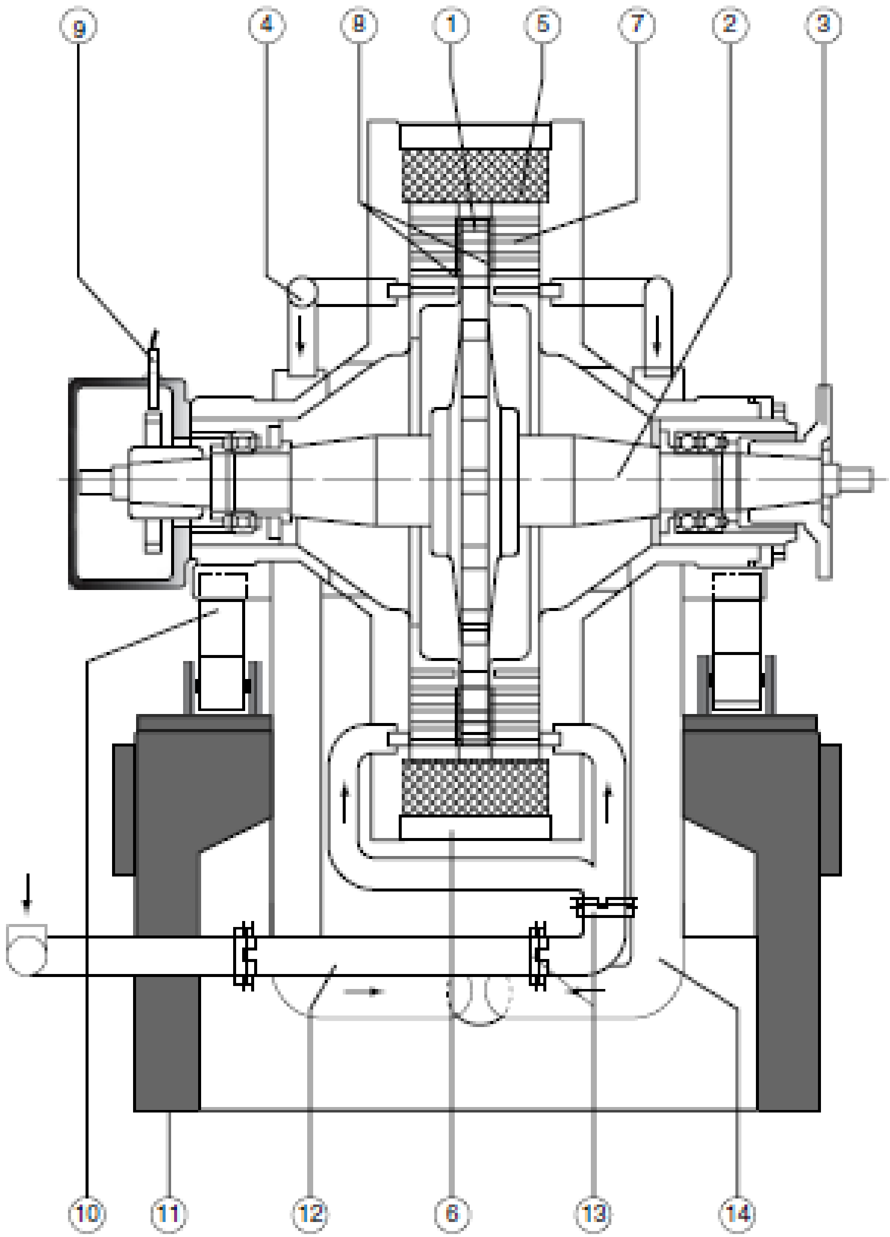
ANTAM
Asian and Pacific Network for Testing Agricultural Machinery

Dynamometer

- The accuracy of the dynamometer that measures torque and speed is fundamental to other derived measurements made in engine testing
- In the trunnion-mounted or cradled dynamometer, the power absorbing element of the machine is mounted on bearings and the reaction torque is restrained and measured by force measurement device mounted tangentially at a known radius from the machine axis.

Trunnion mounted dynamometer





Schenck Dry gap, Disc type Eddy current dynamometer
1. Rotor, 2. Rotor Shaft,3. Coupling flange, 4. water outlet with thermostat,5.Excitation coil,6. Dynamometer housing,7. Cooling chamber,8. Air gap, 9. speed pickup,10,Flexure support, 11. Base,12. water inlet, 13. Joint, 14. water outlet pipe.

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

Calibration and Errors

- Calibration is done by fitting calibration arm- Check correctness of length of calibration arm- (should be stamped on arm)
- Standard mass used for calibration.
- The value of G should be correct to local elevation and latitude (error of around 0.1% is possible)
- The calibration must be done without connecting the driveline
- The calibration arm is counterbalanced. The load cell system is warmed up to operating temperature
- The cooling water supply at no load condition is connected (parasitic force due to flexible lines connecting to cooling water inlet should be minimized)
- The torque calibration is made by loading and unloading. Hysteresis should be reduced by gently moving the cradle back and forth

Matching dynamometer to load

- When a high grade dynamometer is expected to give a torque indication that does not differ from the absolute value by more than about ±0.1 per cent of the full load torque rating of the machine.
- Assume a dynamometer rated at 400 Nm and 2400 rpm (100kW) with an error band of ±1Nm throughout the entire span being used to used to test a Power tiller Engine of 40Nm 2200 rpm (9.2kW)rpm. The torque indicated at 40Nm true value will be 39Nm to 41Nm
- It is necessary to match the size of the dynamometer as closely as possible with the rating of the engine.

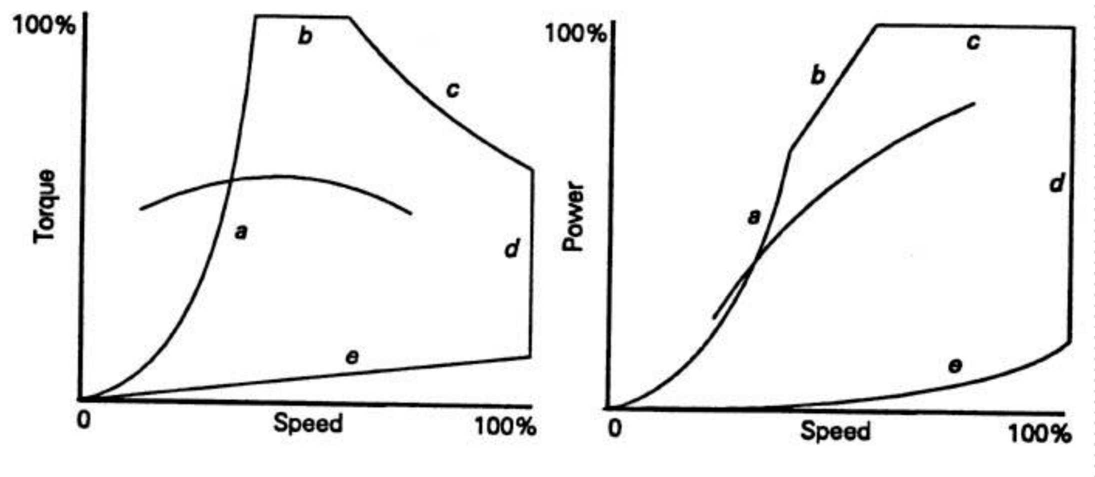
Dynamic variations

- The shaft sped is measured by toothed wheels or enCoders.
- The angular acceleration is calculated and the inertial torque is corrected

$$Inertial\ torque = Inertia\ of\ \ dynamometer\ rotor \times Angular\ \ accleration$$

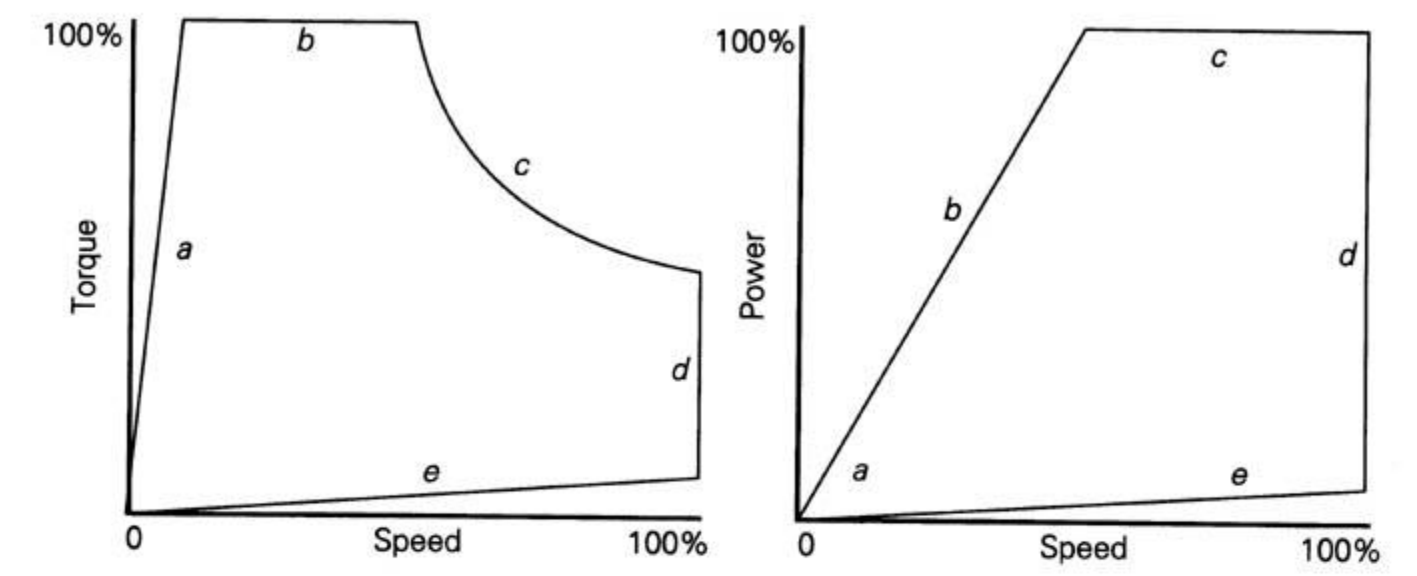
Hydraulic dynamometer

- Dynamometer full (or sluice plates wide open). Torque increases with square of speed, no torque at rest.
- Performance limited by maximum permitted shaft torque.
- Performance limited by maximum permitted power, which is a function of cooling water throughput and its maximum permitted temperature rise.
- Maximum permitted speed.
- Minimum torque corresponding to minimum permitted water flow

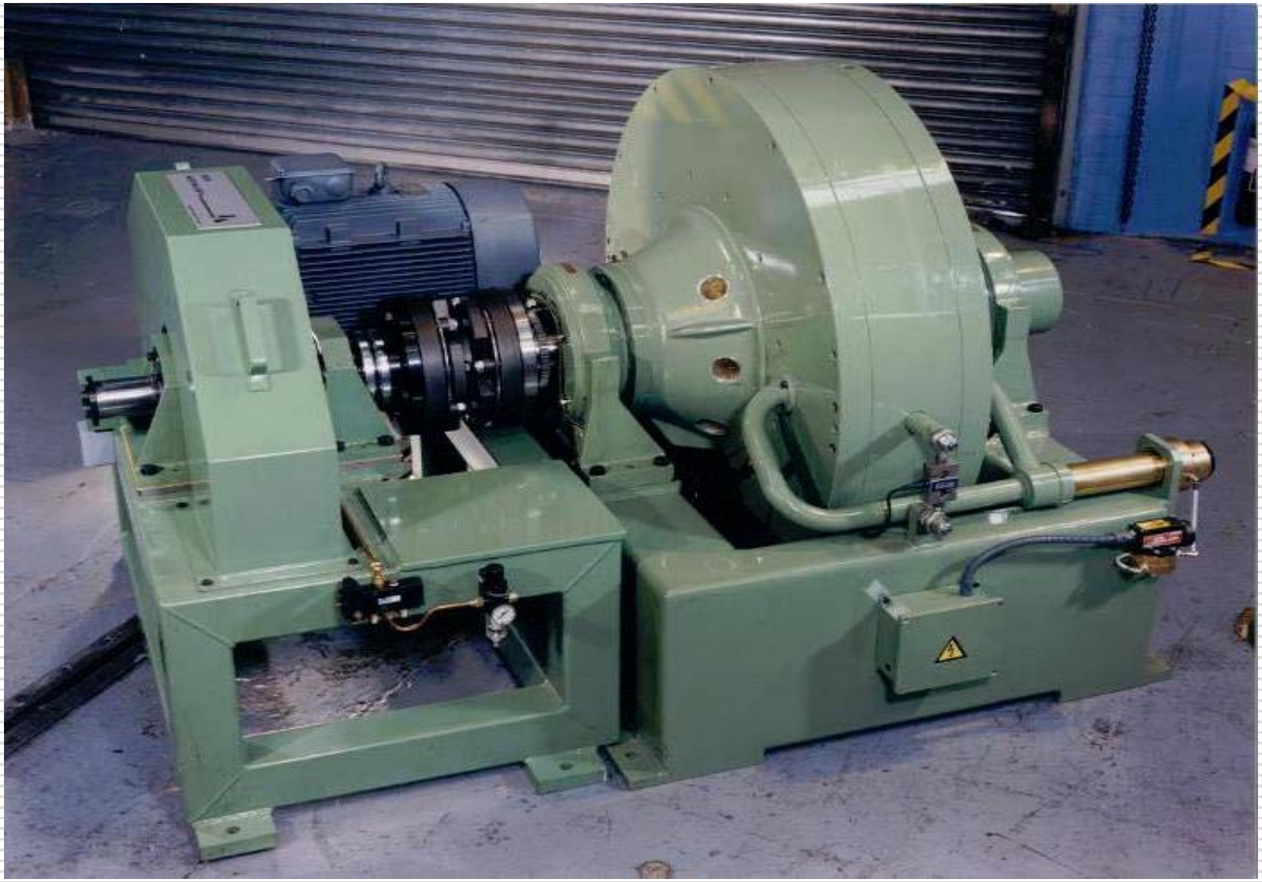


Electrical dynamometer

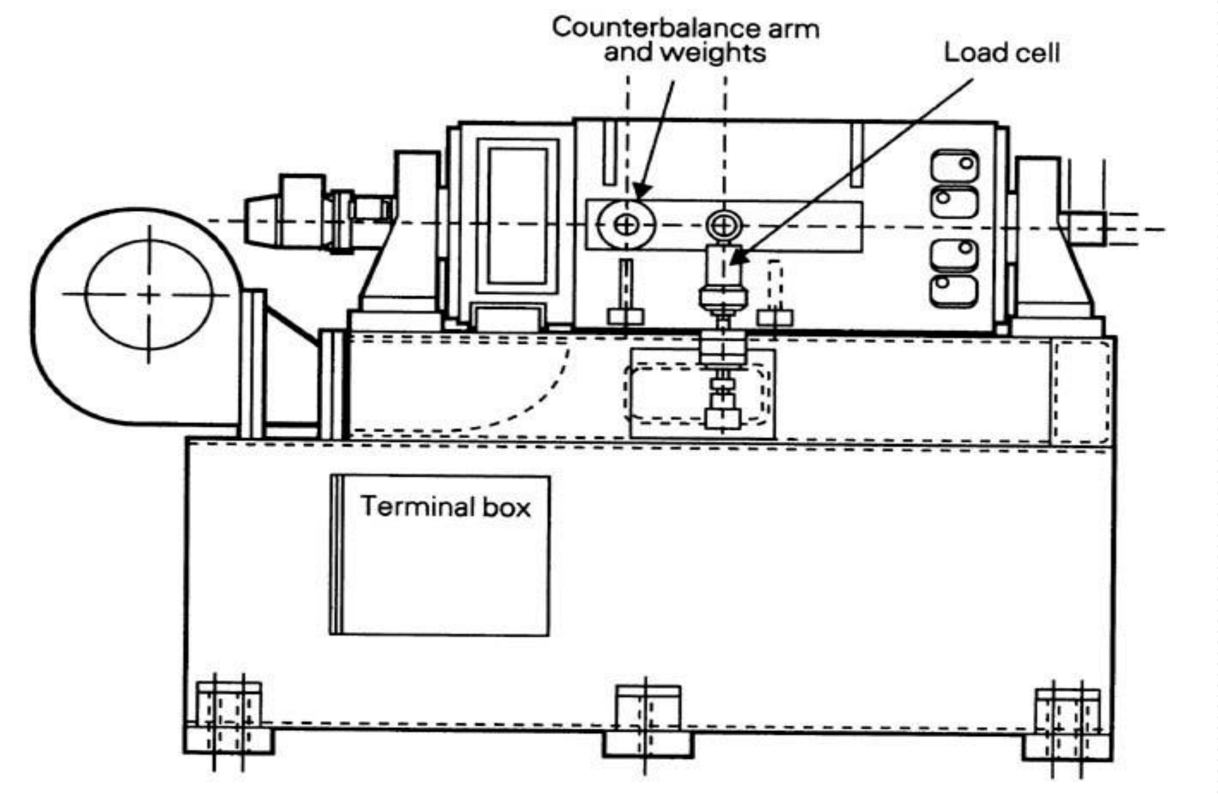
- Constant torque corresponding to maximum current and excitation.
- Performance limited by maximum permitted power output of machine.
- Maximum permitted speed

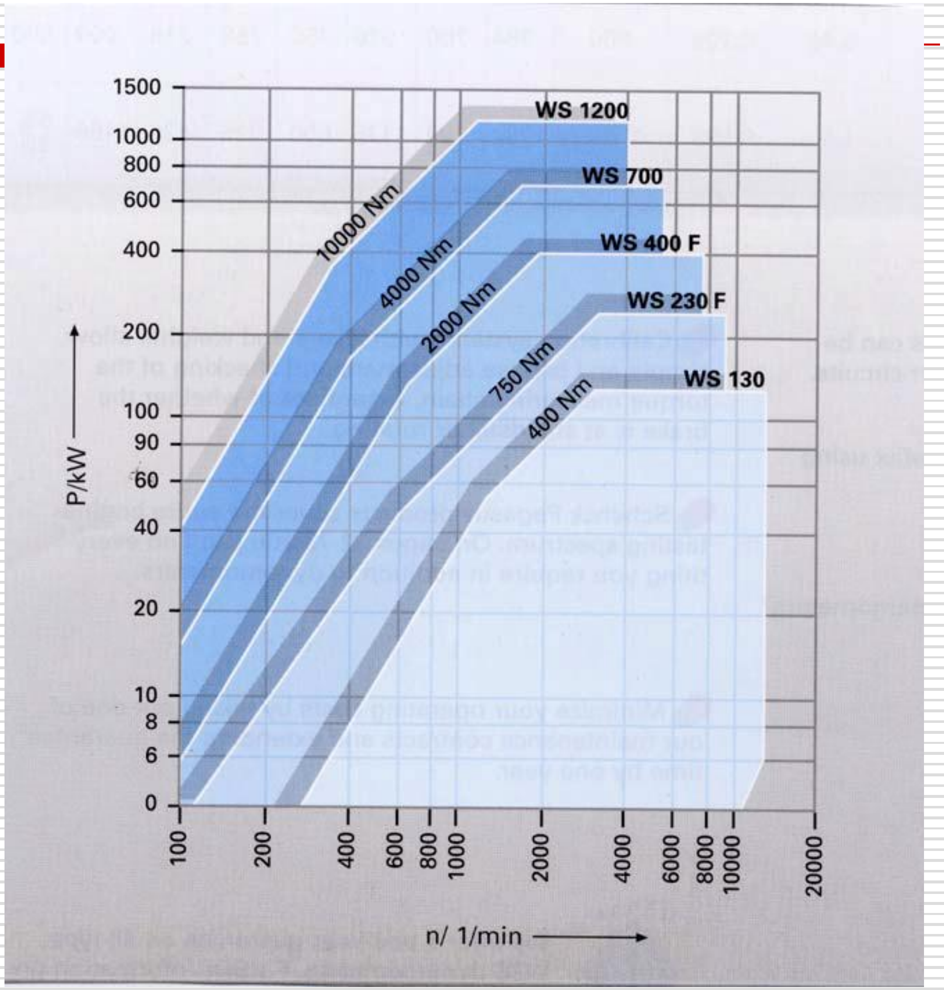


Eddy current Dynamometer

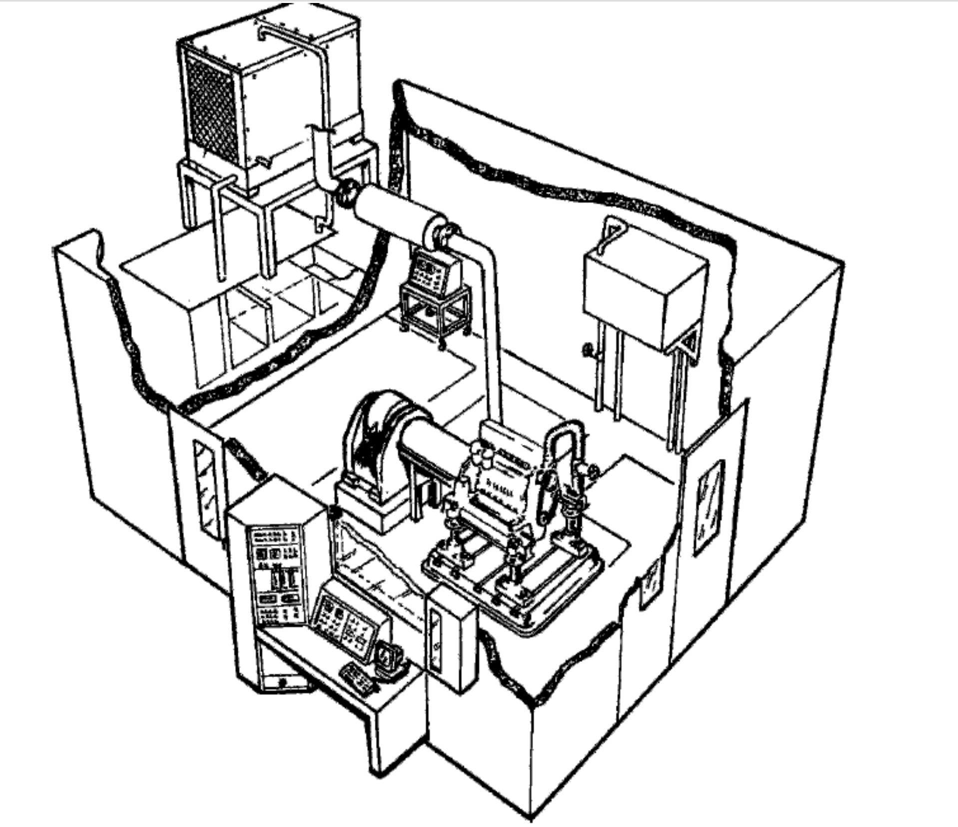


DC-AC generator



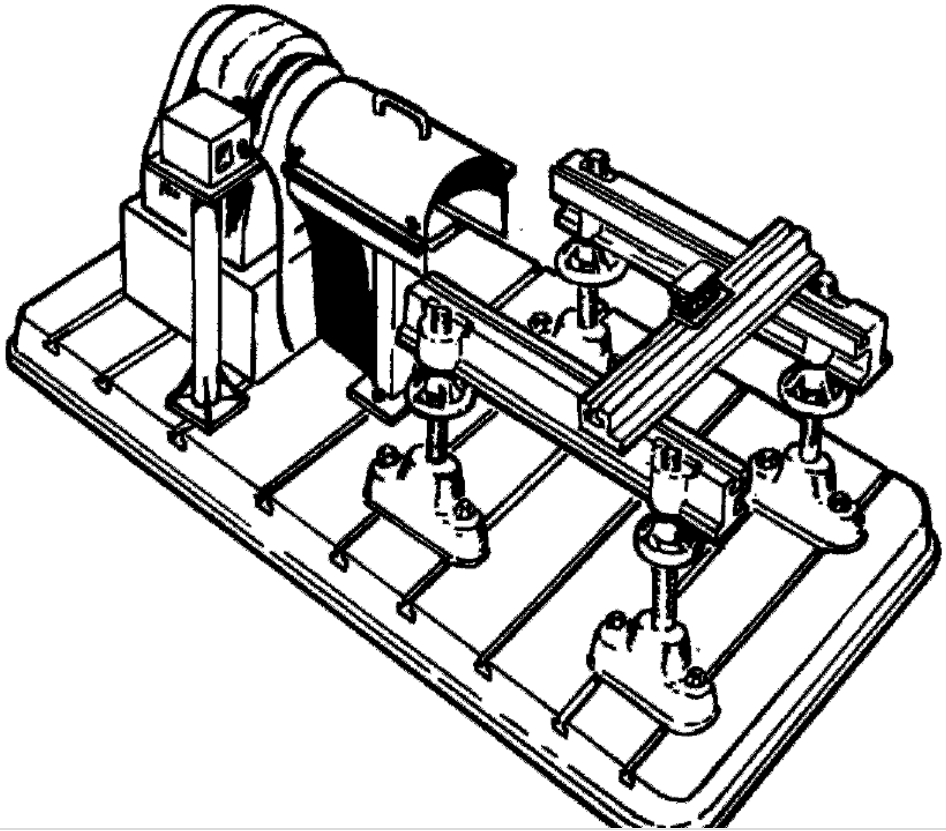

WS 1200
WS 700
WS 400 F
WS 230 F
WS 130
10000 Nm
4000 Nm
2000 Nm
750 Nm
400 Nm
P/kW
n/ 1/min
1500
1000
800
600
400
200
100
90
60
40
20
10
8
6
0
100
200
400
600
800
1000
2000
4000
6000
8000
10000
20000

The test cell



General purpose test cell arranged against an outside wall with control desk ‘side on’ to engine

Engine mounting



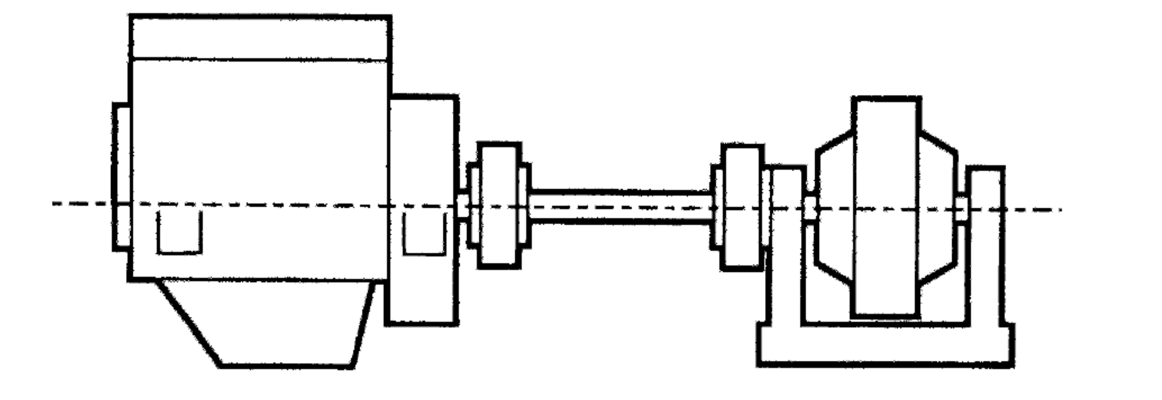
Dynamometer and engine mounting stand on a common tee-slot bedplate. This type of stand, requiring crane loading of the engine.

Coupling the engine to dynamometer

- The bare engine behaves different from a in- vehicle engine with the clutch - gearbox and drive lines with associated damping of torsionl vibration and inertia.
- Particular care is necessary where the moment of inertia of the dynamometer is more than about twice that of the engine
- The loads imposed by the drive shaft and its un balanced forces should not overload the bearings of the engine or dynamometer.

Torsional vibrations in drive line

- The engine–dynamometer system may be regarded as equivalent to two rotating masses connected by a flexible shaft



Drive line

- The dive line should be designed to take the maximum torsional shear stress imposed.
- The maximum stress due to torque T on a shaft of diameter d is given by

$$\tau = \frac{16T}{\pi D^3} Pa$$

- Incase of tubular shaft

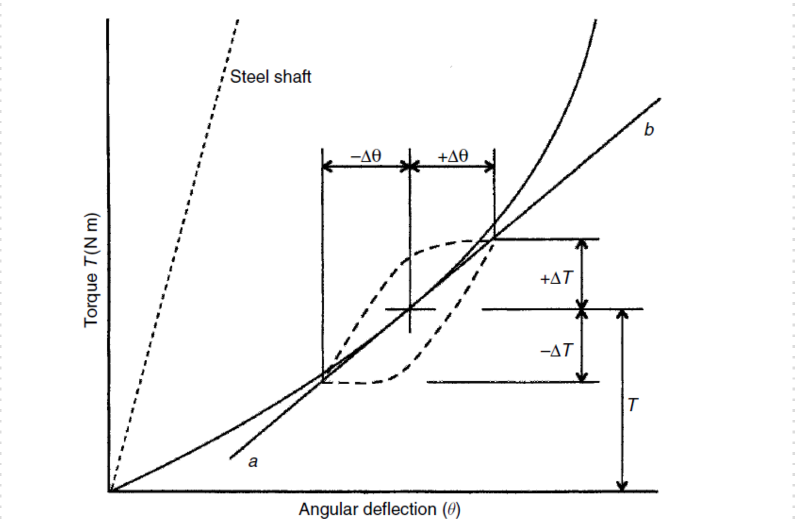
$$\tau = \frac{16TD}{\pi\left[D^4 - d^4\right]} Pa$$

- Stress concentration at transition from shaft to flange should be reduced by providing generous fillet
- At the semi circular ends of a sunk parallel key, The stress concentration may exceed 2.5 – Better to use keyless element couplings
- Cyclic stress due to torsional oscillations should be considered
- Considering the fatigue stresses the value of τ can be taken as 100MPa

Coupling

- Quill shaft with integral flanges and rigid couplings
- Quill shaft with toothed or gear type couplings
- Conventional ‘cardan shaft’ with universal joints
- Multi steel disc flexible coupling
- Elastomeric flexible coupling

Torsional stiffness of steel shaft and flexible coupling



Safety of drive line

- The whirling shaft can draw in loose cloth and flexible material and hence proper protection is needed for operator safety
- The Not only is the failure of a high speed coupling shaft potentially dangerous, as very large amounts of energy can be released, it is quite common.
- The ideal shaft-guard will contain the debris resulting from a failure of any part of the drive line and prevent accidental or casual contact with rotating parts,
- A really substantial guard, preferably a steel tube not less than 6mm thick, split and hinged in the horizontal plane for shaft access, is an essential precaution. The hinged 'lid' should be interlocked with the emergency stop circuit to prevent engine cranking or running while it is open.
- Many designs include shaft restraint devices loosely fitting around the tubular portion, made of wood or a non-metallic composite