Teaching Materials

Advanced Agricultural Machinery and Management (ES 4101)

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Dept. of Agric. Eng. & and Soil Science,

Rajarata University of Sri Lanka

Advanced Agricultural Machinery and Management

ES 4101 (2/25:10)

Teaching Materials

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PREFACE

These teaching materials on Advanced Agricultural Machinery and Management (AS 4117) is prepared by myself, to be submitted to the 162th Faculty Board, Faculty of Agriculture, RUSL on 02nd November, 2016. Hereafter, these materials could be used by the undergraduates who are enrolled for the Advanced Agricultural Machinery and Management (AS 4117) in B.Sc. (Agric.) Special Degree programme in Rajarata University of Sri Lanka to improve their learning environment.

November, 2016 G.V.T.V. Weerasooriya

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1. INTRODUCTION

1.1 Course Capsule

Tillage, traction: optimum soil condition for tillage, relevant soil properties, mechanics of interaction between soil and tillage equipment and traction devices; testing and evaluation of farm machinery; concepts of machinery management; machinery depreciations; fluid machinery; pump turbine

1.2 Course ILOs

The students will be able to,

1. Explain the concept of Soil mechanics, tillage, traction and rolling resistance with practical application
2. Identify the optimum soil condition for tillage
3. Acquire the knowledge on soil interaction with farm machinery
4. Explain the procedure and impotence of testing and evaluation of farm machinery
5. Explain the basic principles of farm machinery management
6. Calculate the depreciation of farm machinery
7. Explain the fundamental s of fluid machinery with application

1.3 Lesson Sequence

Week	**Lesson Title**	**Number of Hrs.**			**Methods of Teaching**	**Methods of Assessing**	**Change of attitudes**
		Theory	**Tutorials**	**IL**			
1-2	Soil mechanics and Tillage	2	2		L, V, Q/A	QZ, EE	
	Tutorial discussion	2		2	GD	IR	TW, LS, CM
3-4	traction and rolling resistance	2	2		L, V, Q/A	AS, EE	
	Tutorial discussion	2		2	GD	IR	TW, LS, CM

5	optimum soil condition for tillage, relevant soil properties	2	0		L, V, Q/A	AS, QZ, EE	
	Tutorial discussion	1		2	GD	IR	TW, LS, CM
6-7	mechanics of interaction between soil and tillage equipment and traction devices	4	0		L, V, Q/A	QZ, EE	
	Tutorial discussion	2			GD	IR	TW, LS, CM
8-9	testing and evaluation of farm machinery	5	0		L, V, Q/A, D	QZ, EE	
	Tutorial discussion	1		2	GD	IR	TW, LS, CM
10-11	concepts of machinery management	4	2		L, Q/A, D	AS, QZ, EE	
11-13	machinery depreciations	2	2		L, Q/A, D	AS, QZ, EE	
	Tutorial discussion	2		2	GD	IR	TW, LS, CM
14-15	fluid machinery	4	2		L, V, Q/A, D	AS, QZ, EE	
Total		**25**	**10**	**10**			

Q/A – Questions and answers TU- Tutorials D –Discussions L- Lectures FV – Field Visits P-Presentations DM- Demonstrations LW – Laboratory Work CS- Case Study V-Videos GD-Group discussion

CM- Communication CA – Continuous attention LS- Leadership TW –Team work O-Organization/ Care CR- Creativity SB- Situational behavior

PR- Peer review by students GR – Group Report QZ- Quizzes IR- Individual Report EE – End semester Examination AS- Assignments GP- Group presentation

1.4 Assessment Strategy

End semester examination	70%
Continuous assessments	30%

Continuous assessments: Assignments, Tutorials, Practical reports

2. TILLAGE AND TRACTION

2.1 Optimum soil condition for tillage and relevant soil properties

2.1.1 Tillage

Tillage is the agricultural preparation of the soil by plowing, ripping, or turning it. There are two types of tillage: primary and secondary tillage.

2.1.2 Particle-Size Distribution

Soil consists principally of mineral and organic particles of various sizes. The variation in size of the particles and the proportionate amount of fine coarse minerals imports for physical and chemical pro

Table 2.1 Particle size distribution

British System		**U.S.D.A. System**		**International System**	
Separates	Ø (mm)	Separates	Ø (mm)	Separates	Ø (mm)
Fine gravel	2.0 – 1.0	Fine gravel	2.0 – 1.0	Coarse sand	2.0 – 0.2
Coarse sand	1.0 – 0.2	Coarse sand	1.0 – 0.5	Fine sand	0.2 – 0.02
Fine sand	0.2 - .04	Medium sand	0.5 – 0.25	Silt	0.02 – 0.002
Silt	0.04 – 0.01	Fine sands	0.25 – 0.10	Clay	<0.002
Fine silt	0.01 – 0.002	Very fine sand	0.10 – 0.05		
Clay	<0.002	Silt	0.05 – 0.002		
		clay	<0.002		

Source: Majumber, S.P. and Singh, R. A. 2002

2.1.3. Soil Texture

Soil texture is the relative proportion of different grain size of mineral particles in a soil. Particles are grouped according to their size, which are called soil separates. These separates are typically named clay, silt and sand.

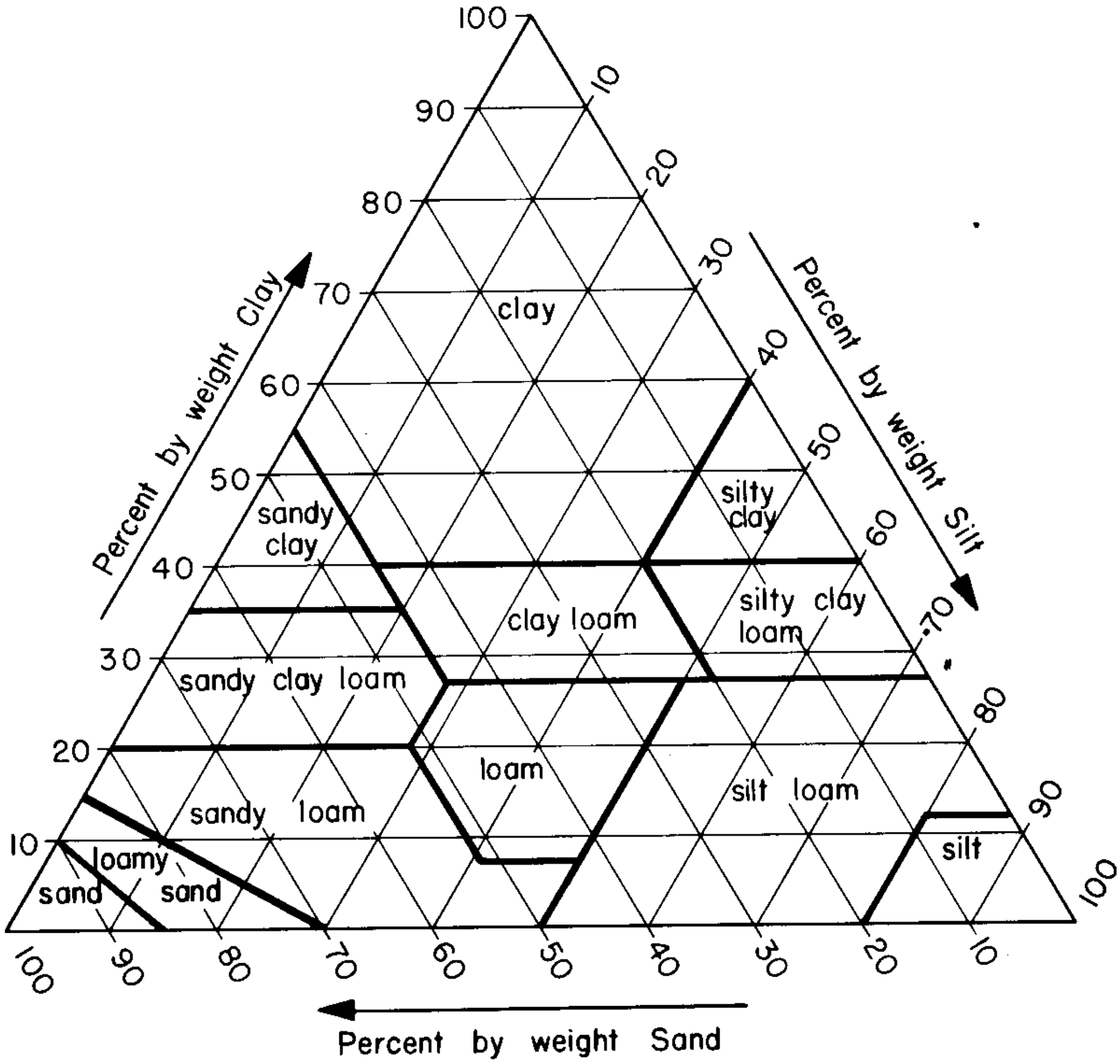


Figure 2.1.Textural Triangle

2.1.4 Soil Structure

Soil structure describes the arrangement of the solid parts of the soil and of the pore space located between them.

2.1.5 Soil Compaction

Compaction is the process by which the soil particles are artificially re-arranged and packed together into closer state of contact.

2.1.6 Consolidation

Consolidation is a gradual process of volume reduction of under the sustained lauding.

2.1.7 Soil Consistency

The physical status of the fine grained soil at particular water content is known as its consistency

2.2 Stress in Soil Mass

2.2.1 Normal stress (σ)

Act perpendicular to a plane. In soil generally compressive, hence compact the soil and increase the density

2.2.2 Shear stress (τ)

Act parallel the plane. Act in pairs as a couple on opposite directions

2.2.3 Soil Strength

- The ability of soil mass to support an imposed loading
- The capacity of a soil to resist or endure an applied force
- Soil load bearing capacity

2.2.4 Measurement of Soil Strength

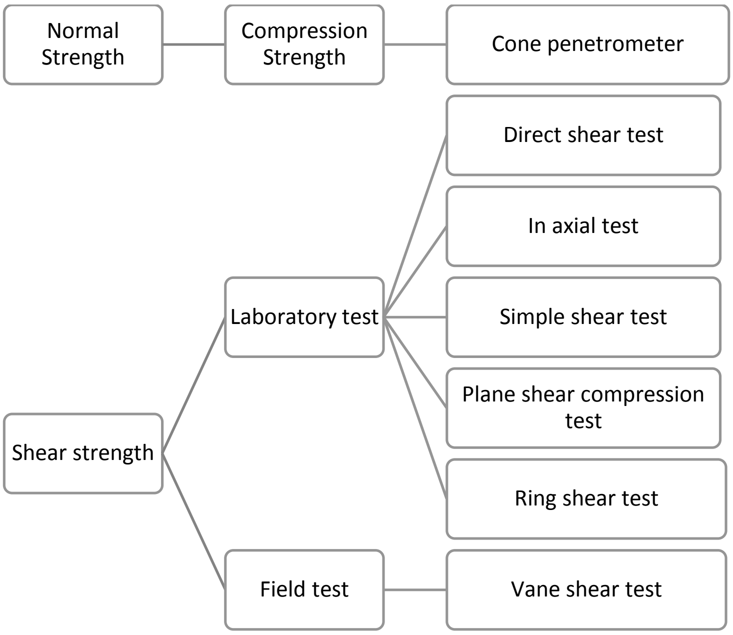


Figure 2.2 Measurement of Soil Strength

2.2.4.1 Measurement of Soil Compression Strength

- Use cone penetrometer
- Unit N/m^2

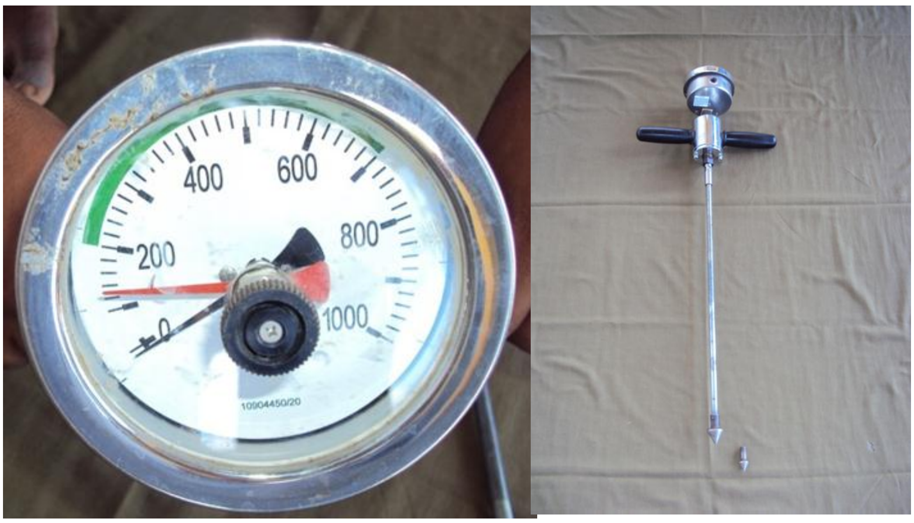


Plate 2.1 Cone Penetrometer

2.2.4.2 Measurement of Soil Shear Strength

Vane Shear tester

Plate 2.2 Vane Shear Tester

- Consist of thin bladed vanes that can be pushed into the soil with minimum disturbance
- A torque applied to rotate the vane is related to the shear strength of the soil

$$K_{shaft} = \left[\frac{\pi D_s^3}{2}\left(\frac{h}{D_s} - \frac{1}{6}\right) + \frac{\pi D^3}{2}\left(\frac{H}{D} + \frac{1}{3}\right)\right]$$

$$\tau = \frac{T}{K_{shaft}}$$

τ - Calculated Shear Stress in Pascal

T - Measured Torque in Nm

K_{shaft} – Revised Vane Shear Constant in m^3

D - Shear Vane Diameter in m

D_s - Shaft Diameter in m

H - Shear Vane Height in m

h – Immersion Depth of the Vane in m (Burns *et al.*, 2009)

2.3 Mechanics of Interaction between Agricultural Soil and Tillage Equipment

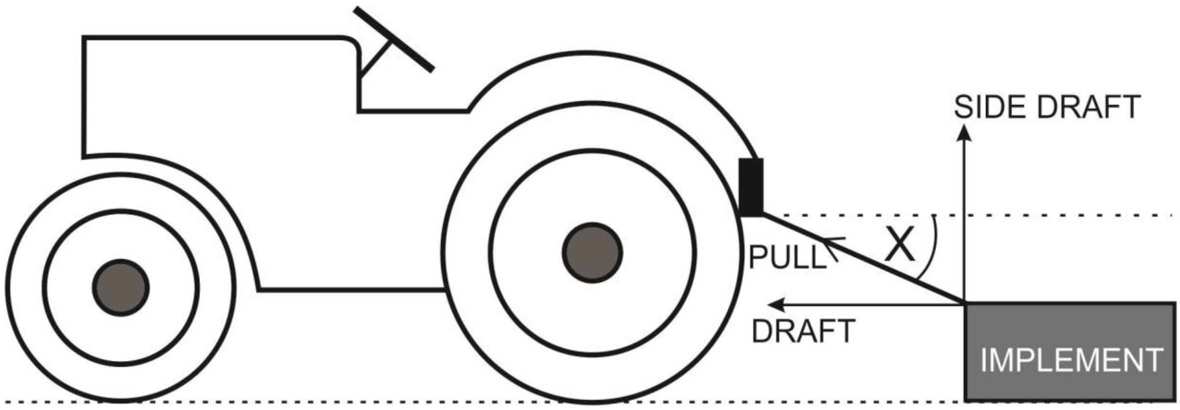


Figure 2.3 Systematic Diagram of Tractor with Tillage Implement

Force – Any action that change or tend to change the state of rest or motion of a body

Pull – The total force exerted upon the implement by a power unit. Generally at some angle above the horizontal may or may not be parallel to the line of motion.

Draft – Horizontal component of pull parallel to the line of motion

Side Draft – Vertical component of the pull perpendicular to the line of motion

Specific Draft – Draft per unit area of tilled cross section. Usually in N/cm^2

Torque – The moment of the force tending to produce rotation about a point. Unit Nm

Work – The production of force (in direction of motion) time the distance through which the force acts. Units Nm or Joule (J)

Power – Rate of doing works. Units kW or hp

Draw bar power (Dbp) – Power actually required to pull the implement at uniform speed.

Kilowatt – hour – The quantity of work performed when one kW is used for one hour

2.3.1 Forces acting upon a tillage tool

A tillage implement moving at a constant speed is subjected to three main forces that must be in equilibrium.

1. Force of gravity acting upon the implement
2. Forces acting between the implement and the tractor
3. The soil forces acting upon the implement

Useful soil forces – Tool must overcome the forces in cutting, lifting, breaking or pulverizing and turning the soil

Parasitic soil forces – Frictional and rolling resistant forces that act upon stabilizing such as land side and sole of a plow or upon supporting wheels.

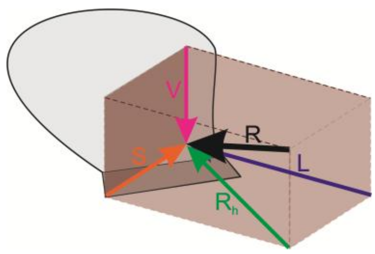


Figure 2.4 Forces Acting on Tillage Tool

R – Resultant of all soil forces acting upon the tool

L – Longitudinal or directional component of R

S – Lateral component of R

V – Vertical component of R

R_h – Resultant of L and S

All tillage tools consist of inclined planes for applying pressure to the soil. Frictional forces are involved due to sliding action of soil. Frictional forces due to sliding soil on soil

$$\mu = F/N$$

μ – coefficient of friction

F – Frictional force tangent to the surface

N – Normal reaction (Normal force)

Frictional forces due to movement of soil on metal (adhesive forces). As adhesive forces are due to moisture films, magnitude varies with the moisture content (Figure 03).

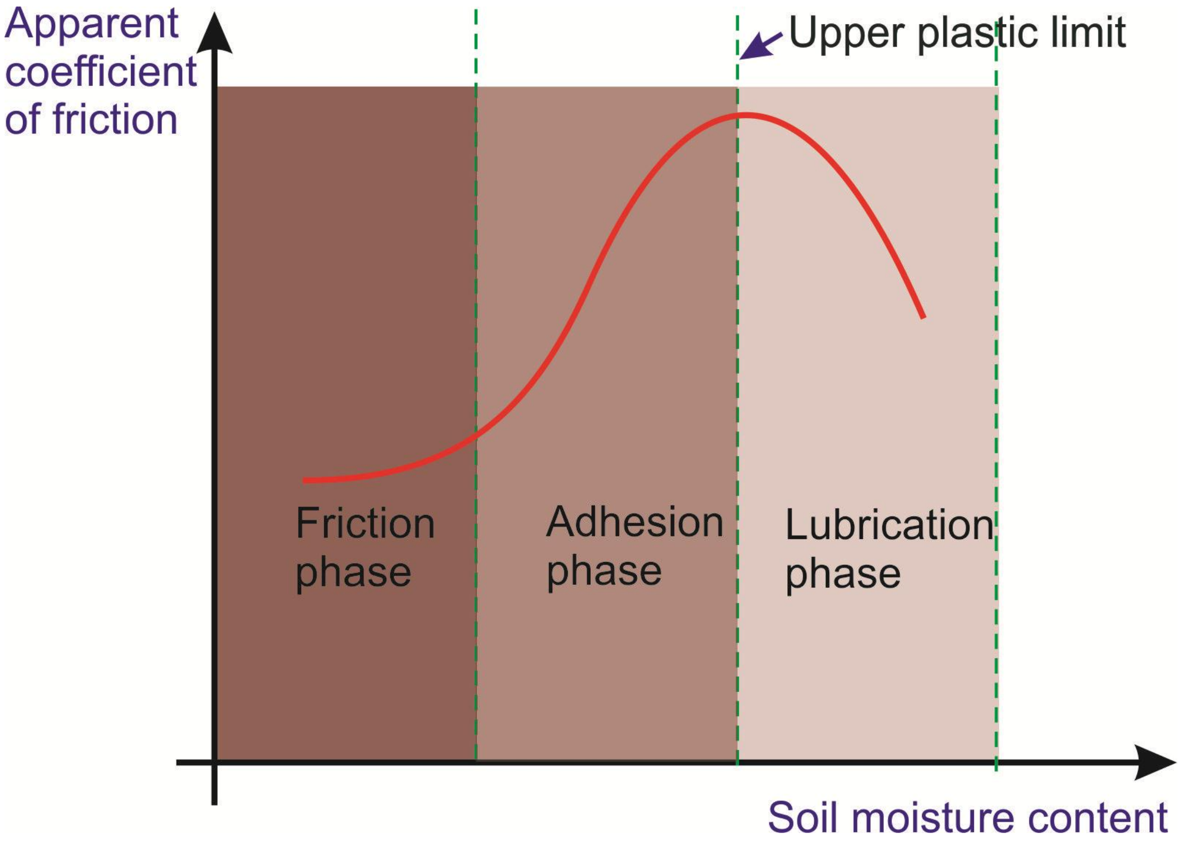


Figure 2.5 Apparent Co-efficient of friction with soil moisture content

Soil characteristics that effects abrasiveness are,

- Hardness
- Shape and size of soil particles
- Moisture content of soil

Abrasive resistant of the tool depend on

- composition of materials
- Hardness
- Strength

– Toughness

A layer of special abrasive resistance alloy (nonferrous chromium- cobalt – tungsten or high carbon iron based alloy containing chromium, tungsten, manganese, silicon and molybdenum) is used on cutting edges of tillage tools to reduce wear rates. (Hard facing or hard surfacing)

2.3.2 Factors Effecting Draft of a Plow

– Soil type
– Soil condition (MC and BD)
– Plowing speed
– Plow bottom shape
– Depth of plowing
– Width of cut
– Types of attachments to the plow
– Plow adjustments

Example 2.1:

A tractor operates at a speed of 8.8 km/h and use 6x356mm mould board plow bottom. If plowing depth is 140mm and unit draft is 5.51x $10^4 Nm^{-2}$. Calculate;

a) Plowing rate (ha/h)

b) Total draft requirement

Example: 2.2

Tractor operates at speed of 5.6 km/hr. 4x355 mm wide mould board plow is attached to it and plowing depth is 137.5mm.

a) If the field efficiency is 78%, calculate the plowing capacity per day. (for 8h)
b) If the soil resistance is 5.51 x 10^4 Nm^{-2}, calculate the total draft requirement.
c) What is the approximate HP of the tractor?

Example: 2.3

A tractor with 4x500mm mould board plow is used to plow 10 ha land. Tractor manipulate the 10 h /day.

I. When the tractor speed is 8km/h calculate the days that required for finished the work.
II. If the area is increased up to 20 ha and working period per day change up to 9hrs, calculate the plowing width when farmer want to finish work at previous time period.

Example: 2.4

A farmer has to plow one hectare field at the forward speed of 2.5 km/hr. using a single cattle plow with a bottom width of 150 mm. If the weight of the draught animal is 500kg and it can pull equivalent pull of 10% of its body weight. Calculate,

a) Power developed by the animal
b) Time taken to plow the field

Example: 2.5

A four bottom moldboard plow travels at a forward speed of, 6.5 kmh-1, width of a plow bottom is 320 mm and the depth of working is 140.5 mm. Determine,

a) The field capacity in ha/day, if it work 6 hours per day
b) The total draft, if the soil resistance is 5.62 x 10^4 Nm^2

Example: 2.6

A tractor operates at speed of 6.3 km/h. 4×346 mm wide mold board plow is attached to it and ploughing depth is 126.5 mm.

a. If the field efficiency is 76%, calculate the ploughing capacity per day.
b. If the soil resistance is 5.63Nm^{-2}, calculate the total draft requirement.
c. What is the approximate Horse power of the tractor?

2.4 Traction

TRACTION is the term applied to the driving force developed by the wheel, track or any other traction device.

TRACTION can be defined as the ability of the vehicle tractive element to generate enough force to overcome all types of vehicle resistance force.

The primary purpose of a vehicle tractive element is to provide sufficient;

- Flotation –ability of a vehicle to travel without excessive shrinkage.
- Traction – force for moving a vehicle.

2.4.1 Traction Mechanics

Traction is developed by the interaction of mechanical devices with soil. Theoretical experimental studies and field tests provide the general nature of these interaction for analysis and design of tractive system

2.4.2 Basic Concepts of Traction

Travel Reduction

Travel Reduction (TR): Reduction in actual forward speed that occurs due to increased slippage when the drawbar load is increased. Theoretically, Slip and Travel reduction are not identical although they are often used interchangeably. Travel reduction must occur to develop drawbar pull

- Tire lug must compress the soil allowing it to develop tractive force
- Rear movement results in travel reduction

Determination of travel reduction

- Measure the distance of travel five rounds of rear wheel (S_1)
- Calculate the theoretical distance by radius or circumference (x)
- $Travel\ Reduction\ = \frac{X - S_1}{X} \times 100\%$

Factors affecting for travel reduction

- Soil surface
- Implement
- Lug design of tractive wheel
- Air pressure of tractive wheel

Tractive force

The tractive force is the pulling force exerted by a vehicle, or machine or body.

Traction Ratio

Dynamic Traction ratio (DTR) is the ratio of drawbar pull (Fdb) over the dynamic weight on the driving wheels. A high DTR needed for high drawbar pull. For that;

- Improved lug design
- Radial ply design

Increase weight will also increase pull at the cost of higher compaction and increased stress on the axles

Tractive Power Efficiency

This is a ratio of the drawbar power to the power input into the final drive axle or axels. Tractive Efficiency (TE) is the fraction of axle power (Pa) that is converted to drawbar power (Pdb) by the drive wheels

TE = Pdb / Pa

Factors affecting for lowering tractive efficiency

- Steering
- Rolling resistance
- Slip and friction
- Deflection of the tractive device

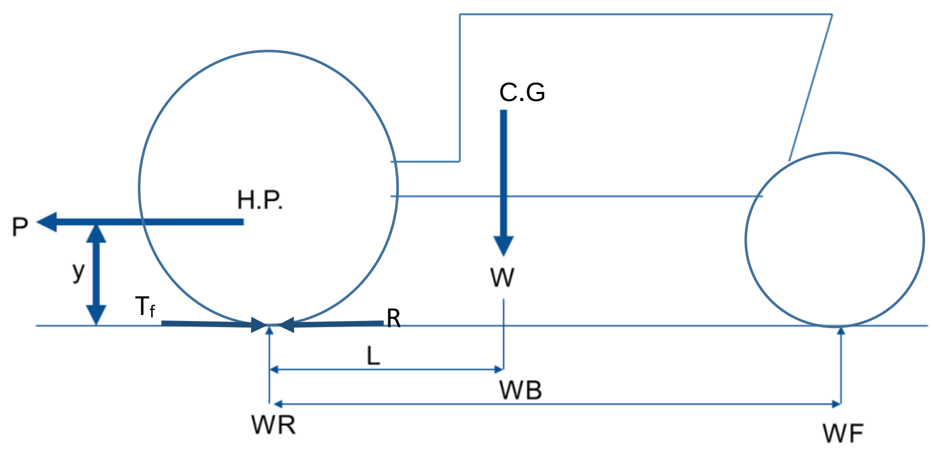
Co-efficient of traction

This the ratio of the tractor drawbar pull to the dynamic load on the tractive device

Factors affecting for coefficient of traction

- Type of traction device
- Type of inflation pressure
- Soil type and status
- Soil moisture content
- Lug design
- Dimension of the tractive device
- Soil pressure distribution

2.4.3 Free Body Diagram for Simple Straight Running 4 – Wheel Tractor



C.G. – Centre of gravity

y – Drawbar height

L – Distance between rear axle to CG

R – Soil resistance

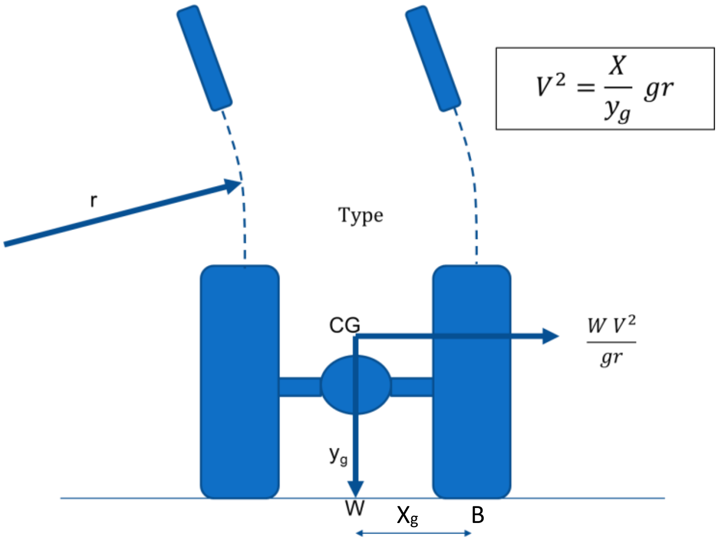
HP – hitch point

WB – wheel base

T_f – Tractive force

Figure 2.6 FBD for simple straight running tractor

2.4.4 Free Body Diagram for Simple bend



X_g = half or differential length, if not it should be given

r = radius of the carve y_g = height of CG

W = weight of the tractor g = gravitational acceleration

Figure 2.7 FBD for Simple Bend

Example 2.7

A four wheel tractor has following chassis features; Wheal length 2.2 m and Height of the center of gravity 75 cm, Determine the maximum speed that can turn 50 m radius bend.

Example: 2.8

A four-wheel tractor has following specifications; Front wheel reaction = 1500 kg, Rear wheel reaction = 2500 kg, Drawbar pull = 1000 kg, Drawbar height = 50 cm and Wheal base = 1 m. Calculate;

a) Weight transfer
b) Maximum drawbar pull

Example: 2.9

A four wheel tractor with 4 m wheel base, 500 mm drawbar height, 5000 N drawbar pull showed 1700 N and 5700 N front and rear wheel reaction, respectively. Determine

1. maximum drawbar pull
2. front weight that required to increase drawbar pull up to 20 000 N
3. At maximum drawbar pull rear wheel reaction

2.4.5 Weight Transfer

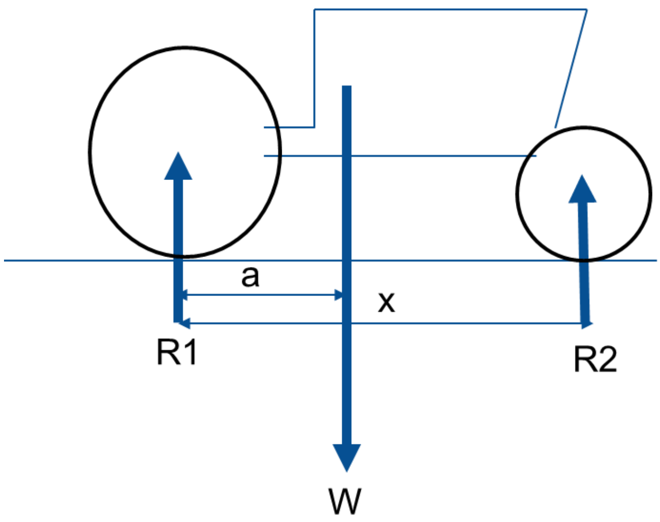


Figure 2.8 (a) without drawbar pull

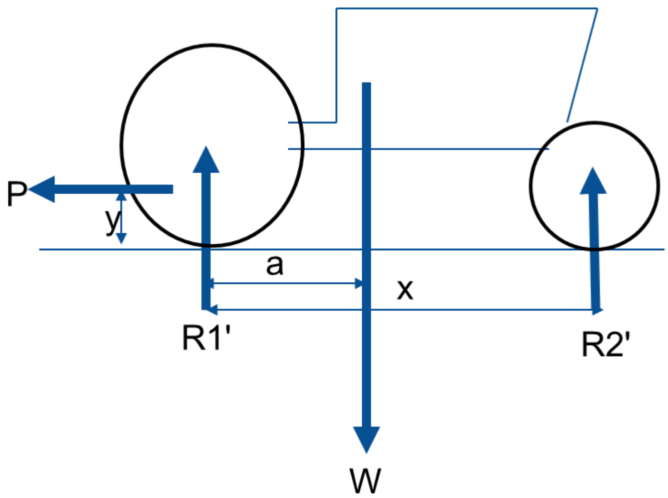


Figure2. 8 (b) with drawbar pull

$$Weight\ transfer = \frac{Py}{x}$$

$$R_2 = \frac{P_{max}y}{x}$$

2.4.6 At Inclination

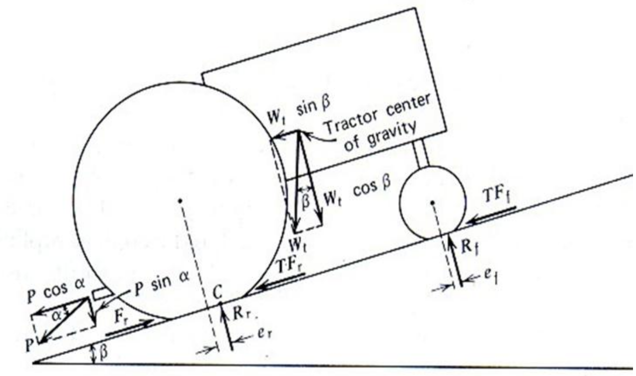


Figure 2.9 FBD at inclination

$F_r = W_t \sin\beta + TF_f + TF_r + P\cos\alpha$

$$P = \frac{F_r - TF_f - TF_r - W_t \sin\beta}{\cos\alpha}$$

F_r- Traction Force

W_t- Weight of tractor

TF- Rolling resistance forces

P - Draw bar pull

α- Angle of line of pull

β- Slope angle

2.4.7 Tractive losses of 4 wheel tractor

Transmission losses – Losses occur power transmission system up to tractive device

Slope losses – Tractive losses due to uneven fields

Rolling losses – Tractive power required for moving /rolling the tractor

Wheel slip losses – Tractive losses due to wheel slipping

2.4.8 Traction Aids

Figure 2.10 (a) Mud wheel

Figure 2.10 (b) Lug design

Figure 2.10 (c) Chain

Figure 2.10 (d) Tracks and half tracks

Figure 2.10 (e) Tyre filled with water

Example: 2.10

A tractor moving with 6 km/h attached with 4 x 400 mm moldboard plow. The line of drawbar is making 20^0 angle with the floor and 325 mm away from the rear wheel floor contact point. Weight of the tractor, wheel base and differential length are 1800 kg, 2.5 m and 1.6 m, respectively. Center of gravity is located at 1 m ahead from the rear wheel and at 0.8 m height form the ground level.

Determine: Drawbar pull, Drawbar horse power, if soil resistance 8×10^3 kg/m^2, plowing depth and the maximum speed that tractor can take 3 m radius bent.

3. TESTING AND EVALUATION OF FARM MACHINERY

3.1 Testing

Analysis of the behavior of a machine compared with well-defined standard under ideal repeatable conditions. Eg: measuring of drawbar pull of a tractor

3.2 Evaluation

Measurement of machine performances under real farm conditions. There are not repeatable. Eg: check the performance of combined paddy thresher in North Central Province of Sri Lanka.

3.3 Beneficiaries of Testing

a) Machinery importers
b) Machinery manufactures
c) Policy makers/Bankers
d) Farmers (Users)
e) Extension workers

3.4 Standard for Testing

- ASAE – American standard
- OECD – European
- ISO – International Standard

3.4.1 OECD

- Mostly used in Agric. Machinery
- Many OECD station around the world
- We are not repeating these tests

OECD Tractor test code

- Complete tractor specification
- Engine power and fuel consumption

- Power and capacity of hydraulic system
- Turning area and turning radios
- analysis of smoke emission
- Selection of center of gravity
- Draw bar performances
- Break performances
- Roll Over Protection Structure (ROPS) test

3.5 Evaluation of Machinery

They do not have international acceptance. Local standards according to the local condition. Have to follow standards

3.5.1 Standards for Evaluation

- Indian Standards – IS
- Japanese Standards – JIS
- Sri Lankan Standards – SLS
- Regional Network for Agric. Machinery Standards – RNAM

SLS have only few machineries. Have to follow the mixture of above standards. Farmer view is very important

RNAM

Economic and Social Commission for Asia Pacific Regional Networks for Agricultural Machinery. 1995. *RNAM Test Codes and Procedures for Farm Machinery*, Technical Series no: 12. Bangkok: United Nations Industrial Development Organization. Sri Lanka also a member of this organization

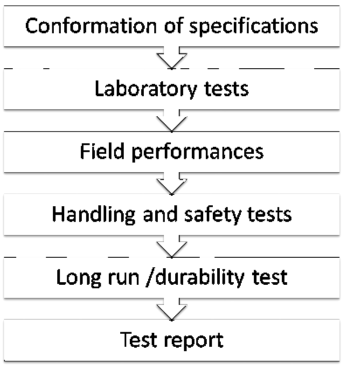
Two Types of Testing and Evaluation - At machinery developing stage and finished product (commercial) testing

Development of Farm Machinery

1. **Information Collection -** Have to collect required information. Analyze collected information and End with the concept

2. **Design Stage -** Design is based on the gathered information. Complete mechanical drawing. Design also test;
    a. Mechanically sound
    b. Whether this machine come to achieve the objective
    c. whether this machine replace labour
    d. Whether this machine create any social problems
3. **Prototype Production -** 1st model of the design. Conduct test for error. Identify the best suited model
4. **Commercial Type -** Conduct proper testing and release to the market

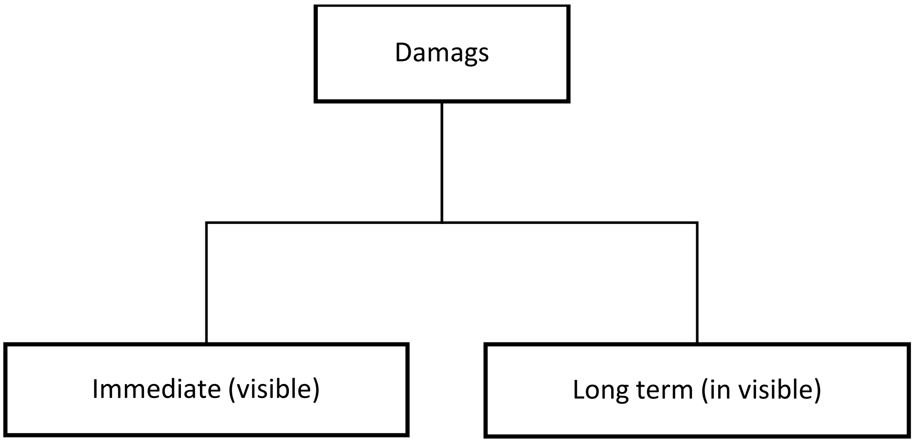
Testing and Evaluation of Commercial type



3.5.2 Testing and Evaluation of Farm Machinery

- Four wheel tractor
- Power tiller
- Paddy reaper
- Thresher
- Sprayer
- Water pump
- Seeders and planters
- weeders

3.6 Safety Test and Ergonomics



Immediate (visible)

- Over-run
- Run-over
- Trap
- Cut – by cutter knife, sharp edge
- Crush
- Falling down from the machine
- Burn from hot parts
- Light/temporary injuries
- Disable
- Death

Long term (in visible)

- Not cause sudden death
- It caused to health condition
- Sound (Noise)
- Vibration
- dust

3.6.1 Noise

Exposing loud sound (120 dB (A) for long time – can hear only large sound. Frequent expose of sound (> 85 dB (A) – measurable hearing losses. Tractor develop 90 – 100 dB (A)

- 90 dB(A), 2 h   No problem
- 90 dB(A), 4 h   Problem
- 100 dB(A), 2 h   Problem

3.6.2 OSHDA

Organization which makes standards to hearing. They produce Equality Continues Sound Levels (ECSL)

- 100 dB(A), 1 h — 84 dB(A) continues
- 100 dB(A), 10 h — 94 dB(A) continues
- 100 dB(A), 20 h — 97 dB(A) continues

Table 3.1 Permissible noise levels

Duration (h)	Noise level dB(A)
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼	115

3.6.3 Measuring of Noise

Use noise level meter. These meter has three scales

- dB(A) for human beings
- dB(B)
- dB(F)

Reducing Noise - Identify the noise places. Use noise reducing methods from;

- Design
- Isolated/enclosed
- Use ear protectors

3.6.4 Vibration

Two types of vibration; Whole body vibration and Part vibration. Whole body vibration cause to nerves problem. Measured by displacement meter. >4Hz is damage to nerves system.

3.7 Ergonomics

The application of scientific information about human being to design of objects systems and environment intended for human use. It involves the application of anatomical, physiological and sociological knowledge and methodology to evaluate and optimize performance and human health safety and comport.

Operator work as power source and controller. Hence machine/equipment should be compatible with; size, shape, strength, senses (Version, like) etc.

3.8 Safety Testing

Basic technical requirement for safety are;

1. safety guards
   - Cover (2 or 3 side cover)
   - Casing (all side cover)
   - Enclosure
2. Safety distance
3. Safety devises
4. Safety signs

3.8.1 Safety Measuring Instruments

- Scale – can measure the safety distance
- Push and pull tester
- Sound/noise level meter
- Vibration/displacement meter

4 MACHINERY MANAGEMENT

4.1 Selection of Farm Machinery

- Trade mark
- Trade name
- Models
- Repairs
- Design
- Ease of operation
- Ease of adjustment
- Adaptability to work and conditions
- Selection of Farm Machinery
- Quick change of units
- Maneuverability
- Comport
- Safety
- Other factors (Power requirement, Cost of operation, Initial cost, Years of service expected, Economic -size of the farm/work to be performed)

Selection of farm equipment depend on Size (Extent) and Type (crop). Seasonal nature of farm work hence farm machinery usage relatively short period of time. High cost during the limited time period. Farm machinery should have high reliability high field efficiency. Machinery selection and management are important to designers and users.

4.2 Machinery Selection Criteria

4.2.1 Field Capacity

Amount of processing per hour of time. There are two types; Area basis and material basis.

On area basis

$$C_a = \frac{VW\eta_f}{10}$$

On material basis

$$C_m = \frac{VWY\,\eta_f}{10}$$

C_a – field capacity area basis (Ha/h)

C_m – field capacity material basis (Mg/h)

V – Travel speed (km/h)

W – Machine working width (m)

Y – Crop yield (Mg/ha)

η_f – field efficiency (decimal)

Theoretical field capacity C_{at}/C_{mt} - Field capacity when field efficiency (η_f) is equal to 1

4.2.2 Field Efficiency

$$\eta_f = \frac{\tau_t}{\tau_{ac}}$$

η_f - Field efficiency

τ_t - Theoretical time requirement

τ_{ac}- Actual time requirement to perform the operation

Theoretical time requirement (τ_t)

$$\tau_t = \frac{A}{C_{at}}$$

τ_t - Theoretical time requirement to perform the operation (h)

C_{at}- Theoretical field capacity

A - Area to be processed (ha)

Actual time requirement (τ_{ac})

This can be measured. Larger than theoretical time requirement due to overlap, time for turning and time for loading or unloading

$$\tau_{ac} = \tau_e + \tau_h + \tau_a$$

τ_e – τ_t/K_w – effective operating time (h)

K_w – Fraction of implement width actually used

τ_a - Time losses that are proportional to area

τ_h – Time losses that are not proportional to area

Example: 4.1

A self-propelled combine with an eight-row corn head for 75 cm row spacing travels at 5 km/h while harvesting corn yielding 9.4 Mg/ha. Losses proportional to area total 7.6 min/ha and are primarily due to unloading grain from the combine. Neglecting any other losses, calculate;

a) Field efficiency
b) Field capacity on area basis
c) Field capacity on material basis

4.3 Machine brake down

Machine break down cause to time losses, hence reduction of field efficiency.

Probability of machine break-down time = 1 – operation reliability

4.3.1 Machine reliability

The mean time between failures. Reliability of a group or components or machine with serial relationship – product of individual reliability

4.4 Machinery cost

Three types:

- Cost of ownership – fixed/overhead cost
- Operation cost – variable cost
- Penalties for lack of timeliness

Cost can be calculated:

- Annually Rs/yr
- Hourly Rs/h
- Per-hectare Rs/ha

Custom cost: The price paid for hiring an operator and equipment to perform a given task. Comparing cost and custom cost; determine the purchasing or hiring machine

4.4.1 Ownership cost

$$Ownership\ cost \propto \frac{1}{Anual\ use\ of\ machine}$$

Ownership cost consist with depreciation of the machine, Interest on invest, Cost of taxes, insurance and housing

Depreciation

The reduction of the value of machine with the time and usage. Largest single cost of machine. Several methods are used for estimating

Straight line depreciation

Simple method.

$$\text{Annual depreciation} = \frac{\text{Purchase price - salvage value}}{\text{machine life}}$$

If no data, assumptions: Salvage value; 10% of purchase value and machine life 10 years

Machine life

Wear out - the repair cost goes uneconomical level

Obsolescence

- Machine is out of production
- Parts are no longer available
- can be used another machine to get profit

Interest on investment

- Cash – prevailing interest rate

- Loan – loan interest
- For simplify: Constant annual interest rate is used

Tax

- Sale tax – assessed on purchase price
- Property tax – assessed on remaining value
- For simplify: Constant tax rate for life time
- Use real tax value,
- No tax values: annul tax charge, 1% of purchase price

Insurance

Based on remaining value and use real insurance cost; should have insurance policy. If there is no insurance policy; owner has to bare risk. Therefore cost for insurance. Annual insurance cost: 0.25% of purchase price

Shelter

Shelter is associated with: Batter care maintenance of machine, Improve appearance, and higher resale value. If shelter provide, real shelter cost. If no shelter;

- Economic penalty for reducing machine life and / or resale value
- Shelter cost should be included
- Annual shelter cost 0.75% of purchase price

Cost for taxes, insurance and shelter is assumed as 2% of purchase price

4.4.2 Operating Costs

Cost associated with use of machine (Cost of labour, Fuel and oil and Repair and maintenance)

Cost of labour

- For hired operator – wage of operator
- When owner operate the machine – by alternate use of time

$$\text{labour cost (Rs/ha)} = \frac{\text{labour cost per hour}}{C_a}$$

Cost of fuel and oil

$$C_s = \frac{P_L Q_i}{C_a}$$

C_s – Fuel/oil cost (Rs/ha)

P_L – Price of fuel/oil (Rs/L)

Q_i – Fuel/oil consumed by engine (L/h)

C_a – Effective field capacity (ha/h)

Cost of Oil

10 – 15% of the fuel cost

Cost of repairing and maintenance

Highly variable. Depend on the care of the user

$$\frac{C_{rm}}{P_u} = Rf_1 \left[\frac{t}{1000}\right] Rf_2$$

C_{rm} – accumulated repair and maintenance cost (Rs)

t – Accumulated use (h)

RF_1, RF_2 – repair factors (form table)

P_u – purchase price

$$\text{Average Cost} = \frac{\text{Total repair and maintanenence cost}}{\text{Economic life}}$$

$$\text{Average repair and maintenace cost/ha} = \frac{\text{Average cost}}{C_a}$$

4.4.3 Timeliness cost

- Optimum time period for several field operations.
- Too early/delay – economic penalty
- Timeliness work
  - By increasing machine number
  - Using large machine

$$C_t = \frac{K_\tau AYV}{\lambda_0 T C_a P_{wd}}$$

C_t – timeliness cost (Rs/ha)

K_τ – timeliness coefficient, fraction of annual crop value lost per day (from table)

A – Crop area (ha/yr)

Y – Crop yield (Mg/ha)

V – Crop value (Rs/Mg)

λ_0 = 2, if operation commences or end at the optimum time period

λ_0 = 4, if operation can be balanced evenly about the optimum time

T – Expected time available e for field work (h/day)

C_a – effective field capacity of machine (ha/h)

P_{wd} – probability of a good working day (decimal) from table

4.5 Farm machinery selection

- Selecting appropriate field capacity problem to - farm operators
- Machinery designers
- Optimum capacity is the achievement
- Same field capacity - compatibility

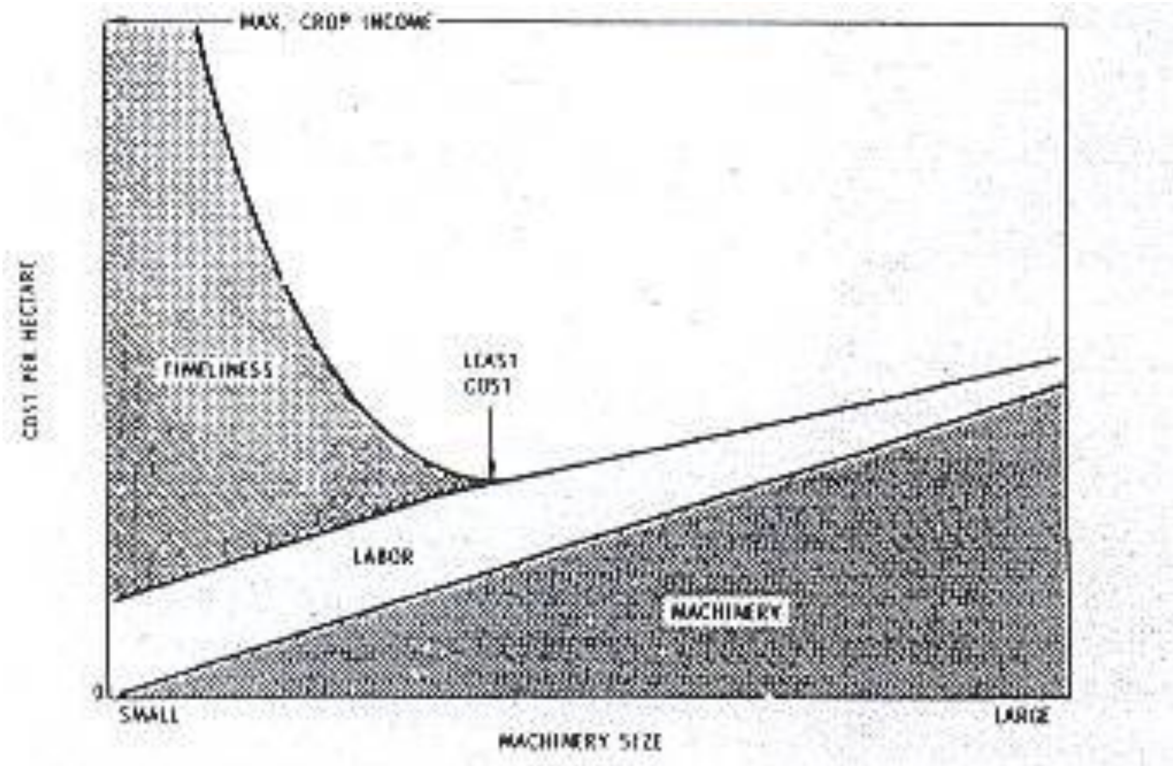


Figure 4.1 Farm machinery selection

4.6 Machinery replacement

All machineries have end of economic life. Reason for Replacement of farm machinery

- Damage by an accident
- Obsolete
- Wear-out

5. FLUID MACHINERY

5.1 Water Pumps

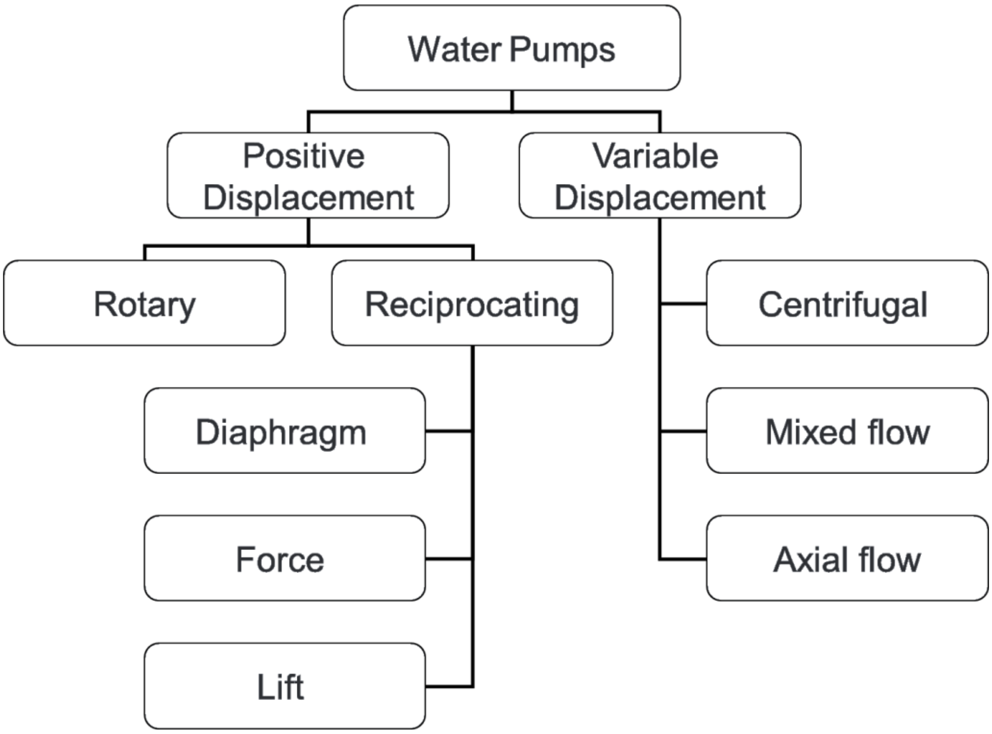


Figure 5.1 Classification of water pumps

5.2 Positive displacement VS variable displacement water Pumps

Table 5.1 Positive displacement and variable displacement water pumps

Positive displacement	**Variable displacement**
Discharge does not vary with the head	Discharge varies with head
Discharge is not depend on the head	Discharge is inversely proportional to head

5.3 Positive Displacement Pumps

5.3.1 Rotary Pump

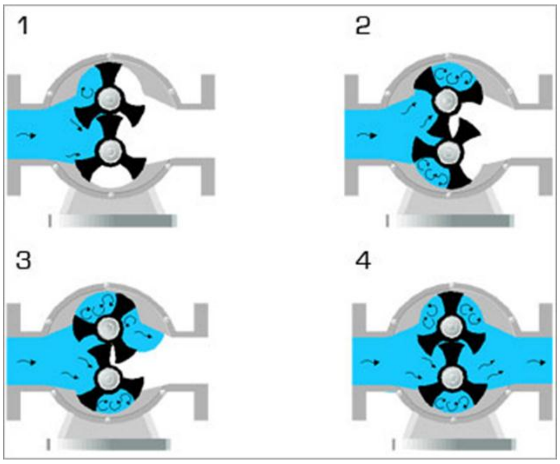


Figure 5.2 Rotary pumps

5.3.2 Reciprocating Pump

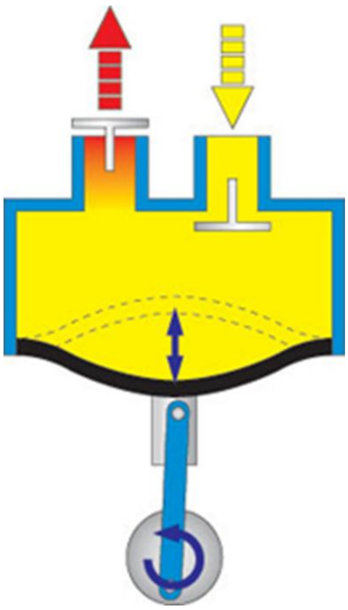


Figure 5.3 Diaphragm Pump

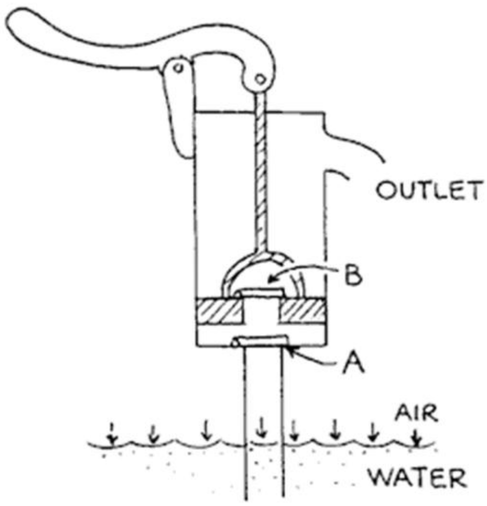


Figure 5.4 Lift Pump

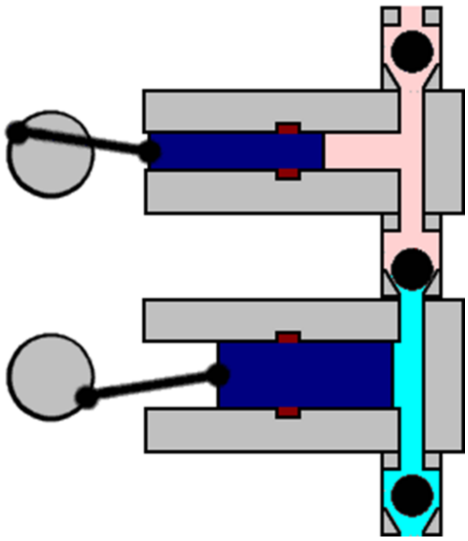


Figure 5.5 Force Pump

5.4 Variable Displacement Pump

5.4.1 Centrifugal Pump

Centrifugal force is generated. Radial flow pump.

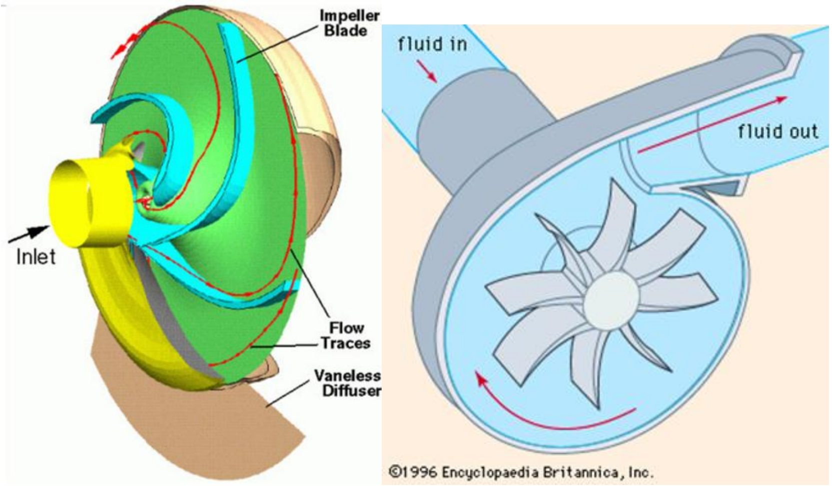


Figure 5.6 Centrifugal Pump

Component of Centrifugal Pump

- Impeller
- Casing
- Out let
- Inlet

Classification Criteria for Centrifugal Pump

1. **Type of casing**

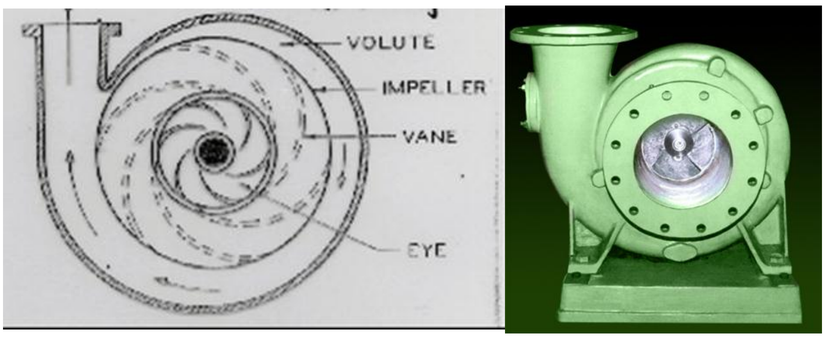


Figure 5.7 Volute Type Casing

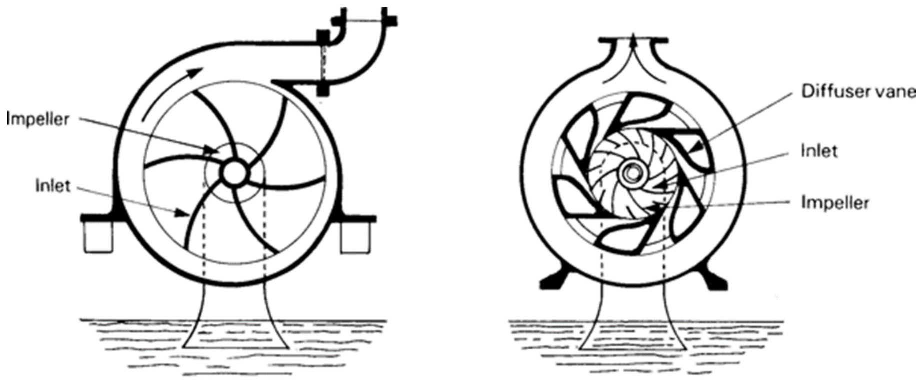


Figure 5.8 Diffuser Type Casein

2. Using stages

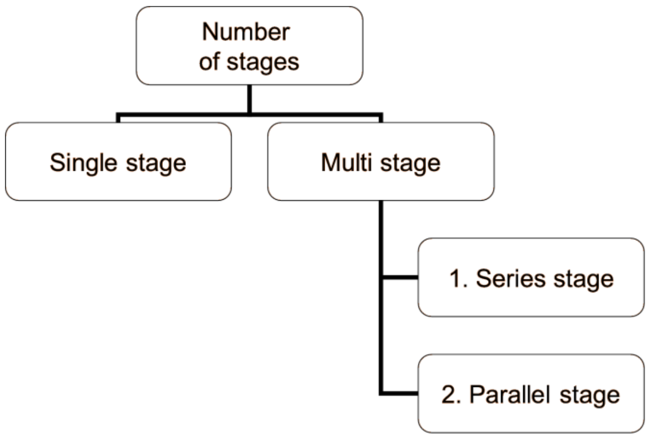


Figure 5.9 Centrifugal Pump Classification as Using Stages

3. **Impeller type**

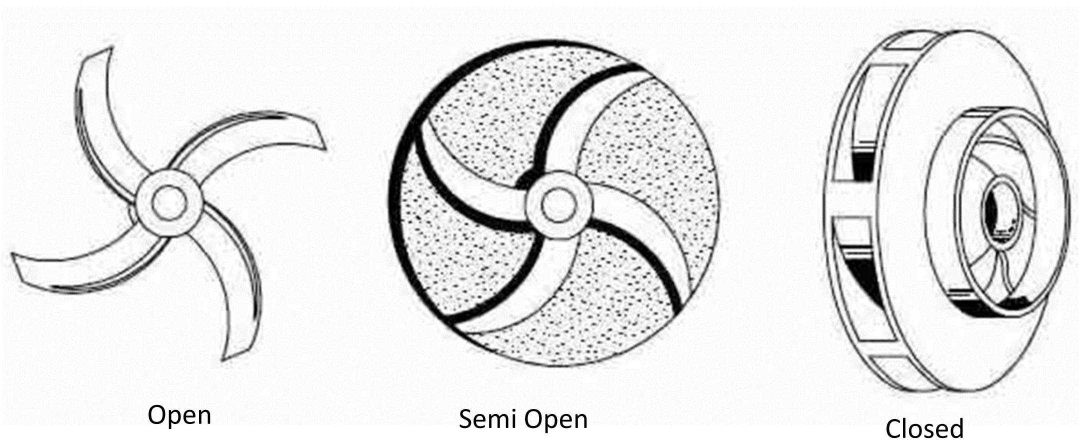


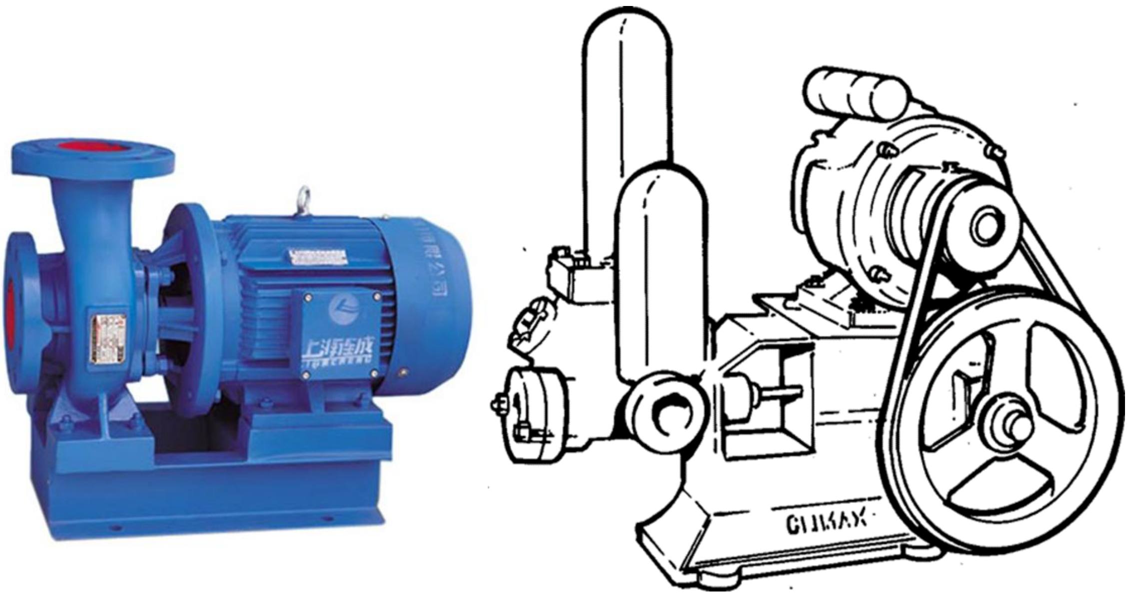
Figure 5.10 Centrifugal Pump Classification as Impeller Type

4. Position of the casing

Vertical Horizontal

Figure 5.11 Centrifugal Pump Classification as Position of the Casing

5. Power supply



Direct Drive Belt Drive

Figure 5.12 Centrifugal Pump Classification as Power Supply

6. Type of suction

- Single Suction
- Double Suction

7. Priming ability

– Self-priming (SP)

– Non self-priming (NSP)

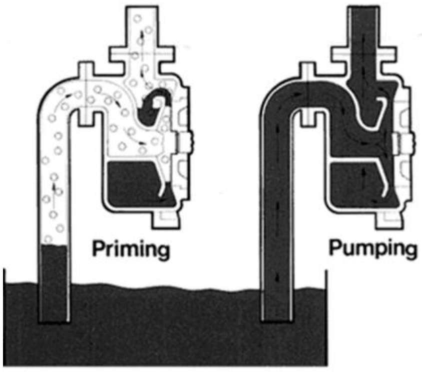


Figure 5.13 Self-priming Water Pump

5.4.2 Axial flow/Propeller/Turbine Pump

Large discharge for low head. Use to flood control

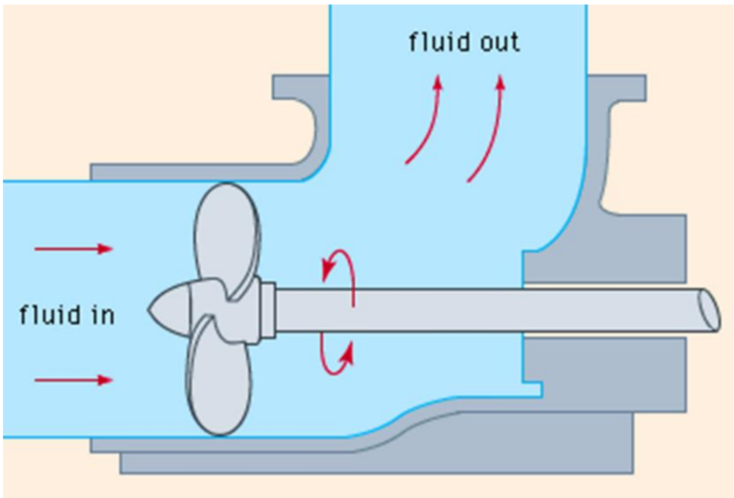


Figure 5.14 Turbine Pump

5.4.3 Mixed Flow Pump

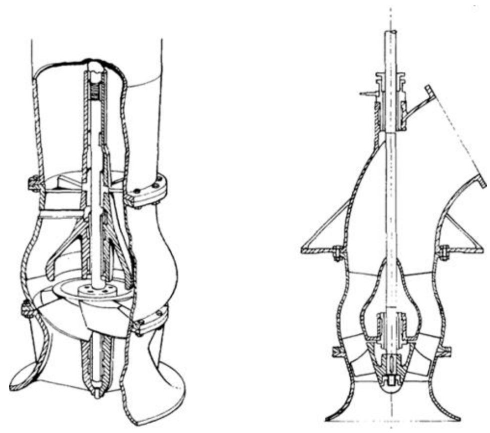


Figure 5.15 Mixed Flow Pump

5.5 Other Pump Types

5.5.1 Jet Pump

Not use in now. Can get higher suction head > 10 m. Having huge casing. Used as deep well kit.

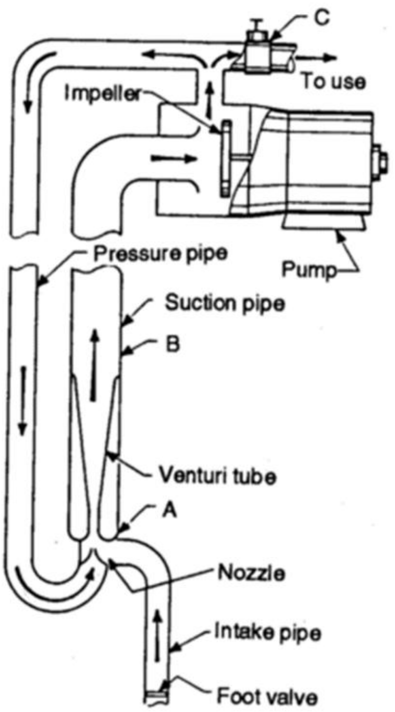


Figure 5.16 Jet Pump

5.5.2 Air Lift Pump

Compressed air is passed though the tube to bottom and increased the pressure of the bottom. Then water is passed through discharge tube.

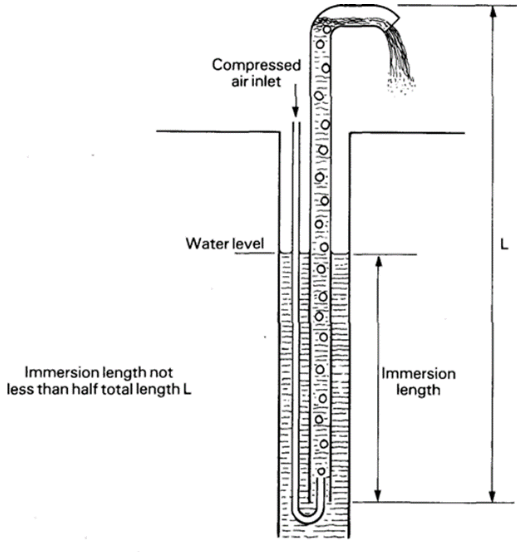


Figure 5.17 Air Lift Pump

5.5.3 Vane Pump

Use to pump high viscous fluid

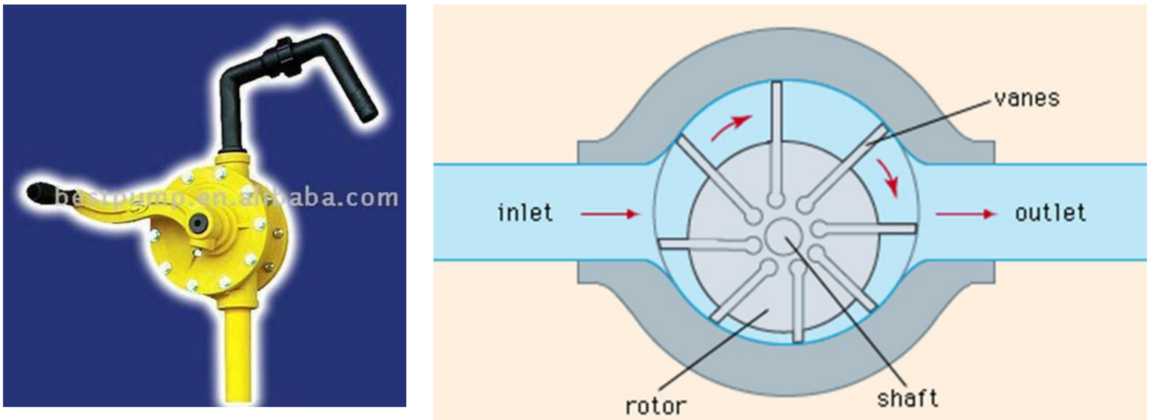


Figure 5.18 Vane Pump

5.5.4 Hydraulic Ramp

Simple devise. Use to lift flowing water to small height.

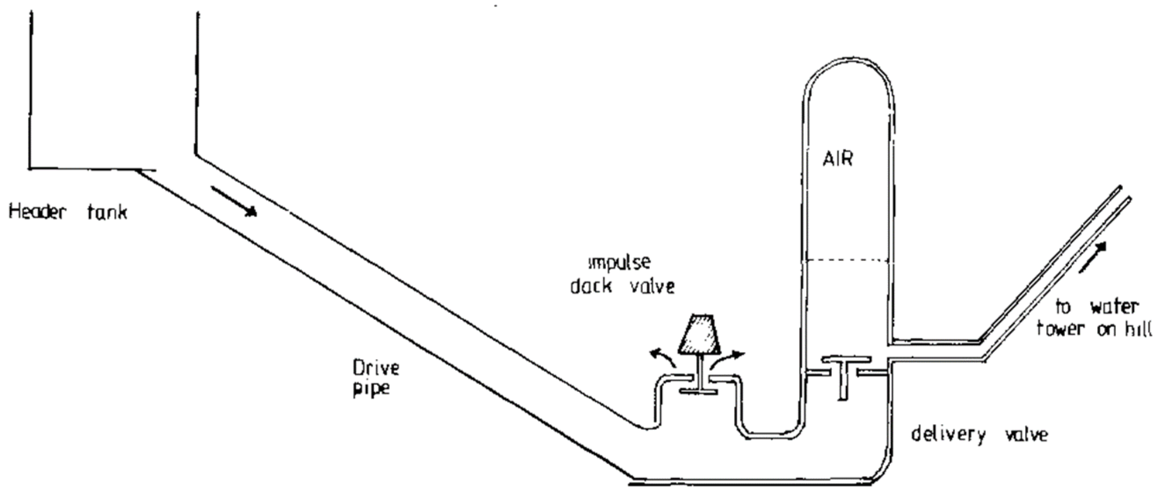


Figure 5.19 Hydraulic Ramp

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