Engineering I

Lesson 2

This is just a cover sheet, turn to the next page to continue.

Hydraulics

Lesson Aim

To explain the principles of hydraulics in relation to agricultural and horticultural use

WHAT IS HYDRAULICS?

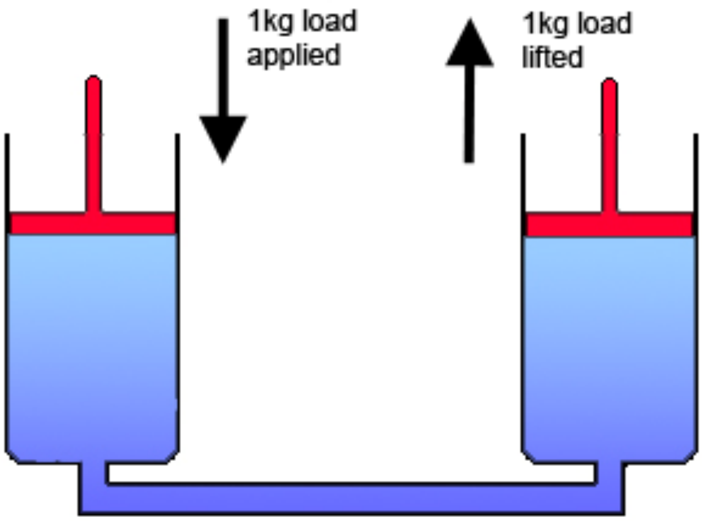
Hydraulics is the science or technology concerned with movement of liquids through pipes or channels.

It is particularly important in agriculture and horticulture for crop irrigation systems. Hydraulic technology is also used in agriculture and horticulture for conveyance and manipulation of mechanical energy. Hydraulic systems are, for instance, frequently used with tractor mounted machines and implements, for lifting and powering. They can be used to run motors to power tools or to power earth moving and handling equipment. Hydraulic systems may be used to power things such as saws, pruners, sprayers, mowers, cultivators, tractor buckets, dozer blades, fork lifts, and travel towers/pruning platforms.

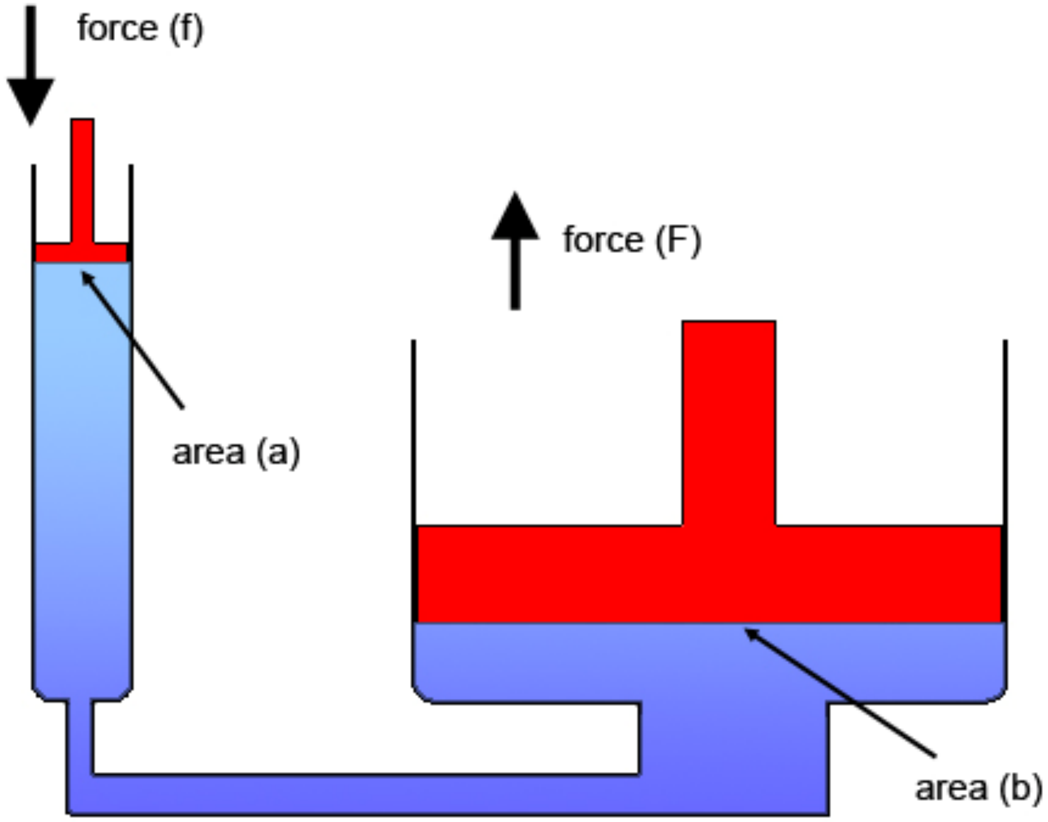
Whether the pipes or channels are carrying water for irrigation, or oil (or something else) in order to transmit energy; many of the concepts, principles and techniques for designing, building and managing the flow of liquid remain the same. Much of what you learn about power transmission hydraulics can be applied to irrigation and much of what is learnt about hydraulics for irrigation, can be applied to power transmissions.

A SIMPLE HYDRAULIC SYSTEM

The important thing to understand is that liquid, generally speaking, is not compressible. When pressure is applied to a liquid in an enclosed system, the pressure gets transmitted equally to all parts of the container. Pascal's Law states that at any point in a fluid the pressure is transmitted in all directions. This concept forms the basis of hydraulic power. The good thing about hydraulic systems is that they are very efficient, as nearly all the force applied at one point will be transferred to another (see following diagram). The pipe in between cylinders can be almost any shape or length, with little loss of efficiency.



Another useful element of hydraulic systems is that *force multiplication* (or division) can be applied to a system by changing the cylinder sizes relative to each other. The following diagram and formula illustrate *force multiplication*:



Because of the *force multiplication* factor, a hydraulic lift enables a small force to lift a large mass. As the pressure under each side of the lift mechanism must be equal, thus the forces on either side are equal (Pascal's Law.) So the following calculation applies:

$f/a = F/A$

In a hydraulic circuit, for the hydraulic fluid to do work it must flow to an *actuator* and/or motor, then return to a reservoir. The *actuator* is a device which uses fluid pressure to produce a force which drives an arm.

Some simple hydraulic systems may be manually operated, such as a hydraulic vehicle jack used for changing tyres on a car or tractor. In this system, a hand lever is used to force oil into a ram cylinder. As pressure builds in this cylinder it forces a piston to move up and the vehicle is then raised. To lower the vehicle you simply release the oil from the cylinder, which drops the pressure so the piston then lowers.

PUMPS

In most agricultural and horticultural situations pumps are used to pressurise or move liquid.

Examples of these situations include:

- Pumping water for irrigation
- Pressurising chemical or fertiliser solutions for spraying or misting applications
- Moving cooling liquid around an engine to prevent the engine overheating
- Moving hydraulic fluid in a power transmission system
- Moving water in water garden features (e.g. Fountains, waterfalls, flowing water courses; through filtration systems)
- Controlling and positioning tractor implements

TRACTORS

One of the most useful mechanisms on a farm tractor is the hydraulic mechanism. It is mainly used for carrying and operating field machinery directly attached to the three-point linkage of the tractor. The simplest system used on farm tractors consists of an oil reservoir, a pump, a cylinder, control lines and control valves. The oil is circulated under pressure by the pump. The pump forces oil into the cylinder where the piston moves and actuates a lever system. This lever system is linked to the machine being used (for example, the power steering of the tractor or the three point linkage).

The pump supplying oil to the ram cylinder may be a gear or multi piston pump driven by the engine or some part of the transmission. This pump is often located in the transmission housing; usually at some point ahead of the clutch so that the hydraulic pump runs at all times when the engine is running and functions independently of the clutch. It is powered by a shaft that transmits power to the PTO (Power Take Off).

Another alternative is for a hydraulic pump to be attached to and powered directly by the engine. A typical 30 horse power tractor will have a pump with an output around 30 litres of oil per minute. When such a hydraulic system is used continuously for a long time; the oil can become quite hot. For this reason, some machinery will have an oil cooler built into the hydraulic circuit.

Oil in a hydraulic system must remain clean and it's common for a system to include a filter. The type of hydraulic oil will vary depending on the make and model of the tractor, so manufacturer's recommendations should be strictly followed. The operation manual should always be consulted if you intend making adjustments to the linkages or control levers of a system.

Check the level of the hydraulic fluid in the system regularly, and maintain the proper fluid level. Wipe the dirt off the filler plug before removing and replacing it. Many systems are fitted with a magnetic drain plug that attracts metal particles and stops them circulating in the system. Keep all the hose connections clean. Service the filter regularly (if one is fitted).

Systems also incorporate a relief valve to protect the system from excessive stress and damage if pressure builds beyond a safe level. Safety valves are incorporated to control the flow of oil, so that excessive pressures do not build up in the system.

Tractor hydraulic systems are controlled by two basic types of systems:

- Draft Control
- Position Control

The tractor hydraulic hitch system was introduced for lifting and lowering implements at the field headland and for lifting implements for transportation from the shed to the paddock. When ploughing the system is switched to a float position so that the plough can work at the correct depth and free follow the soil surface.

Smaller machines have simpler, more basic control systems for hydraulics. These systems are explained in the instruction book that comes with a machine. It is important to recognise that different machines have their own unique features, and it is wise to always familiarize yourself by reading and understanding the instruction book, before attempting to operate any features on a piece of machinery.

TRACTOR AUXILIARY HYDRAULIC TAPPINGS

The tractor's hydraulic system can provide a source of power for the operation of implements that are remotely connected, for example, hydraulic tipping trailers.

Modern tractors are fitted with outlet points where flexible pipes (see photo) can be fitted to convey oil from the tractor's hydraulic pump to an external ram and cylinder fitted on the trailer.

Oil from the tractor is fed under pressure to the trailer mounted ram which is used to raise or move the implement in some way.

HYDRAULIC SYSTEM VALVES

The system must have several valves to direct the flow of oil to the correct part of the system. A relief valve must be incorporated to prevent excessive pressure build up. *Check valves* are used to permit the flow of oil in one direction only. *Control valves* are used by an operator to direct the oil flow to and from the cylinder (control is by a hand lever). These are described in more detail below:

A Single Acting Valve

- This allows power to be used to move something, but in one direction only. The equipment or tool must then be returned to its original position either by gravity or a connected spring.
- A motor can be driven using this type of valve, but only in one direction
- The hydraulic connection can be stopped and started at any point in time; but motors cannot be run in reverse and pressure cannot be exerted in reverse.

A Double Acting Valve

- Power can be exerted in both directions,
- Motors can be operated in reverse
- A ram can be held in any position, and a motor can be stopped and held firm whether from forward or reverse running.

Double Acting with Float Position Valve

- This is similar to double acting, except a float allows the ram to move freely; and a motor can idle if need be.

Flow Control Valve

- This allows the speed to be varied when using a ram or motor, by controlling the flow/pressure in the hydraulic channel.

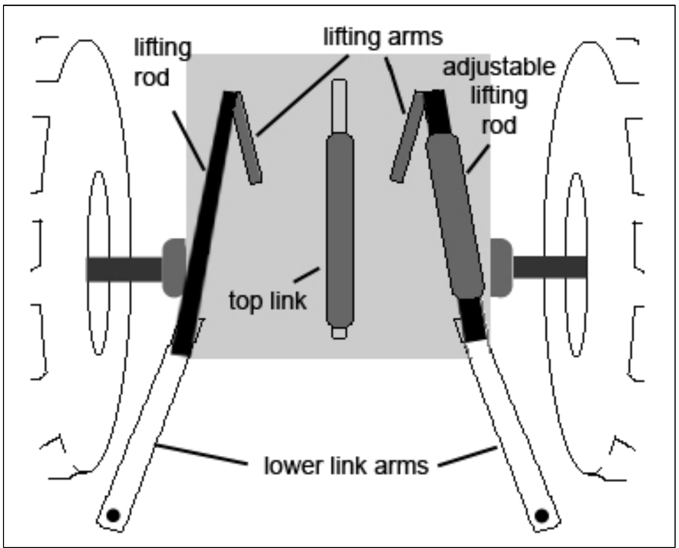
- Greater flow makes a ram move faster (e.g. If lifting a bucket, the bucket lifts faster)
- Greater flow makes a motor rotate faster (e.g. If driving a chain saw, the saw cuts faster).

Activity: Hydraulic systems differ depending on the type of equipment or job they are used for - it is advisable that you undertake further research and reading in order to ensure that you understand the basic principles of the system that you use in your work place.

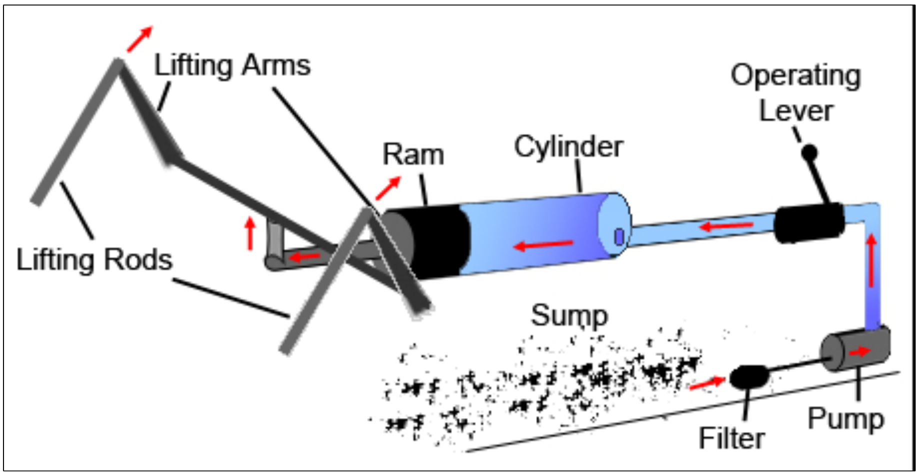
THE TRACTOR 3 POINT LINKAGE

Harry Ferguson, the son of an Irish farmer, invented the tractor *draught-control mechanism* now referred to as the *three point linkage*. He devised this system because he found that under wet conditions the power of the tractor could not be transferred to the soil as there was too much slippage. He reduced wheel slippage using a system of weight transfer through the three point linkage, from the pulled implement to the tractor, so the tractor partially carries the plough during ploughing. His invention involved using the force of the top link which is measured by a spring and the displacement of the spring is transferred to a hydraulic control valve.

The *three point linkage* is located at the rear of the tractor. It is made up of a top link pivoted on the top of the back axle housing and two lower links attached beneath the back axle of the tractor. See following diagram:



The two lower links attach via lifting rods to the lifting arms. The lifting arms are operated by a hydraulic cylinder and ram. These in turn are connected to the driver's operating level, and the oil pump located in the oil sump. Oil forced into the cylinder by the pump pushes back the ram which causes the arms to lift up. The oil is trapped in the cylinder by a valve system that is controlled by the operator's hand lever control. The arms are lowered by operating the lever to allow the oil to escape again. See below:



PRESSURE

Pressure in real terms is the *energy* which is needed to deliver liquid in a *hydraulic system*. More accurately, pressure is the force acting uniformly over an area.

Force is measured in Newtons per square metre (because this measure is very small, it is more practical to use a measure of kilo newtons per square metre).

Another way of measuring force is the "bar". 1 bar is equal to 100kN per sq. metre.

Relationships between Pressure Measurements

1 Newton per square metre (m^{-2}) = 1 Pascal (Pa)

1 bar = 10^5 Pa

1 Atmosphere = 1.013 x 10^5 Pa

1 metre water = 9.80 x 10^3 Pa

A typical operating pressure for a small sprinkler system is 300kN per sq. metre or about 3 bar.

Another common measurement is pounds force per sq. inch (14.5 pounds force per sq. in. equals 1 bar).

MEASURING PRESSURE

With a Bourdon Gauge

Inside the gauge is a curved tube which will try to straighten out when the system is under pressure. This tube is linked to a pointing device which shows the pressure on a scale. These gauges are heavy duty and are frequently used by irrigation experts to measure the pressure on site. The gauge can simply be connected to a water pipe and a reading taken.

Head of Liquid

Pressure is often referred to as "head" (of water or liquid). It can also be referred to as the amount of energy. If a long vertical pipe is connected into a supply pipe, the pressure of liquid in the pipe would force water up the vertical pipe until a point was reached where there was equilibrium between the pressure in the system on one hand, and the force of gravity on the other hand.

One metre of head is equal to 9.8 kPa

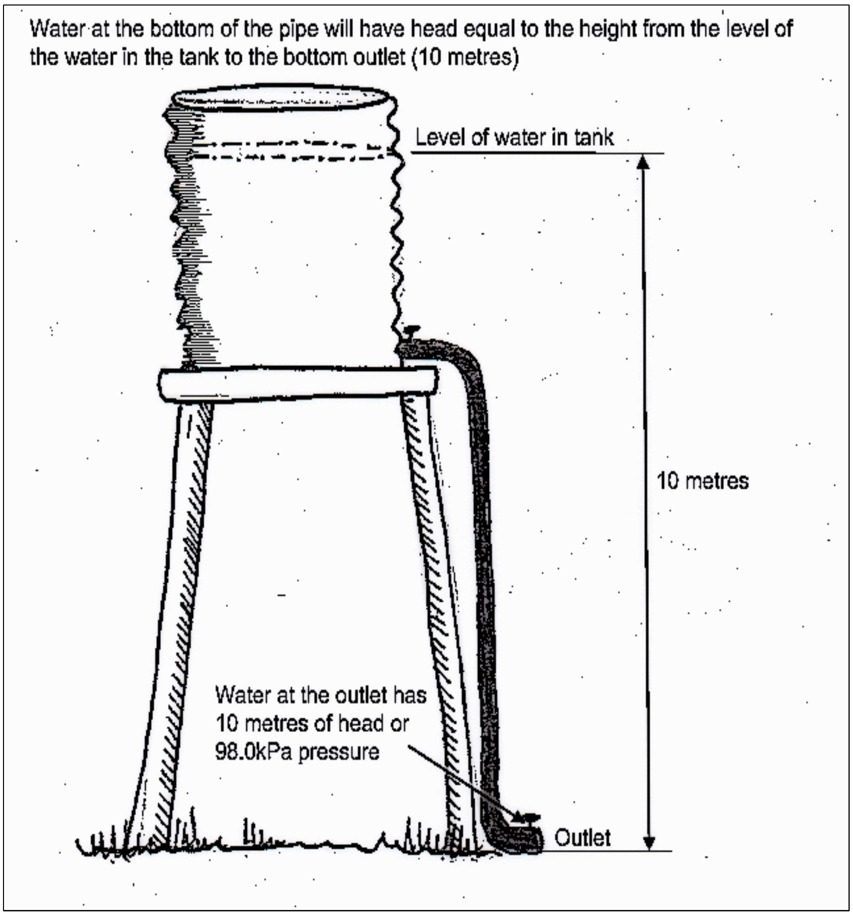
The value for Gravitational Acceleration at sea level is actually 9.81 metres per sec squared. This amount is usually rounded to 10 kPa for convenience sake (see calculation below).

If the height of the liquid is then measured in the vertical section, the pressure can be determined using the following formula.

Pressure (kPa) = Height (m) x Gravity (m/s^2)

Height (m) = Pressure/10

In a gravity fed system, if a water tank has an outlet one metre below the surface of the water, there is one metre of “head” at that outlet. If there is head in a body of water there is also pressure. The following diagram of a simple gravity fed water supply illustrates this principle:



PRESSURE, HEAD AND FRICTION LOSS

These need to be calculated in order to plan efficient irrigation systems and stock watering systems.

Please bear in mind that there are a number of complicated calculations involved in working out the amount of head and estimating head loss in a given system. The purpose of this lesson is only to introduce you to some of these calculations and the terminology involved.

Static Head is calculated when a pipe is full of water but not flowing. If the pressure is measured while the water is flowing in the pipeline, then the pressure will give us the measurement for *Total Dynamic Head* (TDH).

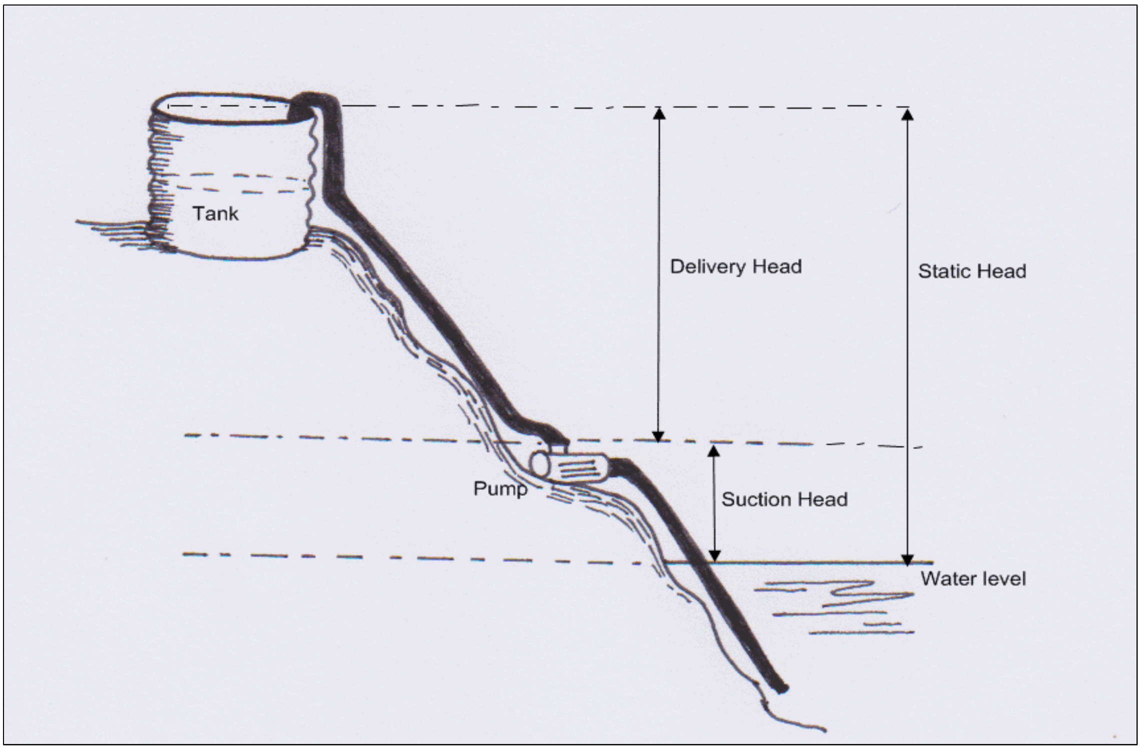
The difference between the flowing pressure or *Total Dynamic Head* (TDH) and the *static head* is the *Friction Loss* in the pipeline.

Static Head: This is the difference in elevation between the surface of the water source and the delivery point.

Static head = delivery head + suction head.

Delivery Head (or Static Height): This is the difference in height from the pump outlet to the delivery point. In other words how far uphill the pump has to push water.

Suction Head (or Static Lift): The vertical distance from the surface of the water at the source to the pump inlet or how far the pump has to actually lift the water.



To choose the right pumping system you need to first calculate the *Total Dynamic Head* (T.D.H). Total Head is the actual height to which water is to be pumped - from the water level at the source to the highest delivery point. Total Dynamic Head (T.D.H) takes into account the friction loss created by the movement of water through the delivery pipeline.

TDH = Suction Head (Static Lift) + Delivery Head (Static Height) + Friction Loss

CALCULATING FRICTION LOSS

In practice, the main way of working out head loss is to use mathematical models which describe fluid flow. These models are based on a number of experimentally derived formulae and depend on the properties of the fluid. Pipe manufacturers produce tables of results of their head loss calculations for their products. The critical factor affecting pipe friction is the internal diameter. It is recommended that the velocity of water not exceed 2m/s, as the head loss increases dramatically after this point.

Bends, junctions, nozzles and outlets are important sites for friction loss. The inside surface of the pipe also creates a large amount of friction. To calculate the loss due to the inside diameter of the pipe:

1. Use a manufacturers table to get the answer with specific measurements previously taken.
2. Calculation:

$$1214.6 \text{ (constant)} \times \text{Length pipe (m)} \times \frac{100}{C} \times \frac{\text{Quantity (L/min)}^{1.85}}{\text{Diameter (mm)}^{4.8655}}$$

= Friction Loss in Metre Head (i.e. the pump needs to generate this amount of energy to overcome this resistance)

Where C = Coefficient of roughness Example:

Old Steel = 80

New Steel = 100

Asbestos, concrete = 100120

Polythene, PVC = 130150

Glass = 175

CALCULATING DISCHARGE OR FLOW

Can be calculated in three ways:

1) Using a Discharge Meter (Flow meter) attached to the outlet or pipe.

It is calculated as: $Q = V \times A$

Where: Q = discharge (e.g. Amount of liquid which comes out of a pipe or outlet)

V = velocity (assuming there is a constant cross section area in the pipe or channel)

A = cross section area

2) Physical technique Discharge from a rotary sprinkler (or tap) can be measured simply by connecting a hose to the nozzle and collecting a known volume of liquid in a container, timing the period required to fill it (e.g. how long it takes to fill a 4 gallon drum).

$$\text{Discharge (cu. m. per second)} = \frac{\text{Volume of liquid (cu. metres)}}{\text{Time taken (seconds)}}$$

3) Set Square Hold a pipe horizontal and watch flow shoot out and using a set square measure the angle of fall and distance.

VELOCITY

Velocity of the liquid within a pipe system can be calculated by:

$$\frac{\text{21.22 (constant) x Quantity (m/min)}}{\text{Internal Pipe Diameter squared}}$$

WATER HAMMER

This is the surging of pressure which occurs when the flow of water in a pipe is abruptly reduced or stopped. The most common water hammer is when the shock of pressure surge is intense enough to cause pounding and vibration of a piping system. There are four causes of water hammer which may be encountered in turf sprinkler systems:

- Valve closure.
- Uncontrolled flow velocity in empty pipes.
- Trapped air in long runs of pipes.
- Reverse flow when pumps stop.

The first two causes occur in any system. The third generally occurs in long runs of pipe such as golf courses. The last occurs in private pump supplies only.

Quick valve closure is the most common cause of shock. *Shock intensity* is measured by the flow pressure existing before flow stoppage occurs plus pressure rise caused by valve closure.

The degree of shock intensity depends on:

- Length of pipe (from point of relief [*] to point of low stoppage).
- Elasticity of pipe.
- Pipe size.
- Flow velocity.

- Speed of valve closure, especially during the last 15% of valve closure.
- Change of flow velocity due to valve closure.

Point of relief is a larger mass of water in the system. It is where the water hammer pressure wave travels back through the piping system between the "point of stoppage" and the "point of relief".

CAVITATION

Cavitation is a big problem for pumps that have to work against a large suction head. As the pressure is low in the pump inlet tiny bubbles form, when these bubbles reach the impellor they collapse violently. This causes the impellor to become pitted and to lose shape. This, in turn, makes the pump less efficient. An affected pump will sound rough like it is full of gravel.

SUBMERSIBLE PUMPS

A submersible pump is a pump and its electric motor together in a protective housing which permits the unit to operate under water. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between pump and the fluid surface. Submersible pumps push water to the surface as opposed to jet and centrifugal pumps having to pull water. Submersibles are more efficient.

Submersible pumps are found in many applications. Single stage pumps are used for drainage, sewage pumping, general industrial pumping and slurry pumping. They are also popular with aquarium filters. Submersible pumps are also used in oil wells. By decreasing the pressure at the bottom of the well (by lowering bottom-hole flowing pressure, or increasing drawdown), significantly more oil can be produced from the well compared to natural production.

In most cases, submersible pumps are suitable for backyard use in fountains and water features. They are considerably quieter, cheaper, and easier to install than above-ground types. Their applications range from small models, which are used for oxygenating aquariums, to larger models, which move water through fountains, waterfalls and ponds.

Most submersible pumps for home gardens use 240 volt electric power. It is preferable to use a low-voltage pump controlled by a transformer to step down the electricity to an acceptable (safe) level. The pump is connected to a power outlet at a specified distance away from the water – the power lead can generally be up to 10 metres long. Some alternative sources of power are in use (e.g. solar) although these systems do not seem powerful enough for the average intended use by landscapers and designers.

The choice of pump depends on factors such as:

- Its performance - how much water it will pump in a given time (e.g. litres/hour), and how high it will pump the water too (height in metres)
- The initial purchase cost
- Operating costs (e.g. power consumption and maintenance)
- How easy it is to install and maintain
- Its expected lifespan

Talk to your local pump supplier (this might be a water garden specialist, an irrigation specialist, or a plumbers supplier) to see which pumps they have available. Consider each of the above factors in helping you narrow down which pump to buy. Don’t be afraid to shop around other suppliers to get different viewpoints, and to check for the best price.

Selection of a pump is based largely on the volume of water that is being pumped through the system, and how high it must be moved. Generally the more features added to the system, the more powerful the pump needs to be. An average sized fountain (around 1.5 metres tall) would need a pump which delivers between 2500 and

5000 litres per hour. A 50cm wide waterfall would need a pump which delivers between 5000 and 9000 litres per hour.

Most pumps include a filter system to prevent pond debris and silt from clogging the motor and restricting the water flow. The filters are designed to protect the pump, not filter the pond. A larger and more sophisticated filter system is needed for cleaning the water. To ensure sufficient biological filtration you first need to determine the volume of water contained in the feature, then select a pump that has the capacity to move the equivalent of one third to one half of that volume in a hour.

The volume of a pond or pool can be determined to a reasonable degree of accuracy using the simple formula Length x Width x Average Depth of the feature. For odd-shaped water features, you may need to separate the feature into sections for measurement purposes, and then total up the volumes for each section, or alternatively estimate an average Width and Length measurement.

The pump should be located as near as possible to the delivery point (e.g. where the water will be released) to reduce power loss through pipe friction. Elevating the pump a little above the pond floor will also help prevent silt blockage. Avoid putting it at the end of a pool opposite a waterfall as this can create currents that stir up sediment and cloud the water.

Pumps built with stainless steel rotors and ceramic shafts offer the benefits of wear resistance and quieter operation. Pumps components made up of plastic are cheaper but are only good for small water features that are operated only occasionally.

IRRIGATION - MEASURING WATER AVAILABLE TO PLANTS

Calculating Field Capacity

1. Wet a soil to near saturation. Cover to prevent drying from evaporation. Let drain for 2 to 3 days
2. Take a sample of soil and weigh.
3. Place in an oven at 105 degrees centigrade to dry out. Weigh and record this second weight after drying. (Do not heat at a higher temperature as this can destroy organic material and give a false reading).
4. Calculate Field Capacity with the following formula....

$$\text{FIELD CAPACITY} = \frac{\text{Loss in Weight}}{\text{Final Dry Weight}} \times 100$$

Calculating Permanent Wilting Point

1. Fill a pot with the soil to be tested.
2. Plant and grow a plant in the pot until its roots penetrates most of the soil (i.e. roots appear at the bottom of the pot). Use a plant which shows signs of wilting easily when wilting point is reached e.g. a petunia, tomato or fuchsia, etc.
3. Now cease watering until wilting occurs. When the plant wilts, seal the surface of the pot with a sheet of plastic to prevent further loss of water through evaporation.
4. Now place overnight in a humid enclosure (i.e. either a humid greenhouse or plastic tent). If permanent wilting has not occurred the plant will recover. If the wilting persists in the morning, you have then reached permanent wilting point.
5. Now calculate moisture content by drying the soil at 105 degrees centigrade, then separating the roots from the soil to find the final dry soil mass.

Available Moisture Range

Available moisture range = Field capacity minus permanent wilting point.

Typical results are as follows:

Soil Type	***Field Capacity***	***Permanent Wilting Point***

Clay	45%	30%
Clay loam	40%	25%
Sandy loam	28%	18%
Fine Sand	15%	8%
Sand	8%	4%

In field situations the following factors are used as constants for calculations. The soil is first determined by the feel test.

Soil type	***Available water (mm/m of soil)***
Clay	135 mm
Clay loam	150
Sandy loam	120
Fine sand	80
Sand	55

A FEEL TEST FOR ESTIMATING SOIL MOISTURE LEVEL

How Moist?	***What It Feels Like***	***% Moisture***
Dry	Powdery and dry	0%
Low	Crumbles and doesn't adhere in a ball, even loosely.	Below 25%
Reasonable	Crumbles but will adhere in a ball.	25 to 50%
Good	Adheres into a ball with a little pressure.	50 to 75%
Excellent	Forms a pliable ball which can be rolled into a cylinder	75 to 100%
Too wet	When squeezed, water drips from the soil	Over 100% Over field capacity.

ROOTING DEPTHS OF SELECTED PLANTS

The following depths are typical for the listed plants when growing without restriction in well drained, fertile soil.

Alfalfa	23 metres	Deciduous Fruit Trees	23 metres
Asparagus	23 metres	Grain crops	1.3 metres

Beans	1 metre	Grass pasture	1 metre
Broccoli	0.7 metres	Clover	to 1 metre
Cabbage	0.7 metres	Lettuce	0.3 metres
Carrots	to 1 metre	Onions	to 0.3 metres
Cauliflower	to 1 metre	Peas	1 - 1.3 metres
Citrus	to 2 metres	Potatoes	to 1.3 metres
Corn	1 metre	Tomatoes	to 2 metres
Cotton	to 2 metres	Strawberries	1 metre

Water extraction by roots

As a general rule in uniform soil, more root development occurs in the upper levels compared to lower levels. The extraction pattern of moisture from soil by plant roots are generally:

1st quarter depth of roots	40%
2nd quarter depth of roots	30%
3rd quarter depth of roots	20%
Deepest quarter depth of roots	10%

IRRIGATION CALCULATIONS

In order to correctly calculate the water use of a crop and how frequent watering is required, a number of statistics need to be compiled. Information that should be gathered includes climatological data which states evaporation rates, and rainfall, etc.

Another piece of data that needs to be gathered is the crop co-efficient. The crop coefficient (sometimes listed as cf) is multiplied by the Class A pan evaporation factor (from meteorological data). This new factor represents the crop's evaporation factor Ea.

Pan Evaporation Rates

The following are standard constant factors used in calculations:

Pan	***Range Mean***
Class A	0.6-0.8 0.7
Australian	0.6-1.2 0.9
British	variable 0.9

Crop Coefficient for Various Crops at Various Stages of Growth:

Crop	***% of crop-growing season***				
	0%	***20%***	***50%***	***80%***	***100%***
Alfalfa	0.55	0.7	0.95	0.9	0.65
Beans	0.2	0.4	0.9	0.6	0.2
Citrus and avocadoes	0.5	0.45	0.45	0.6	0.5

Corn	0.2	0.5	0.9	0.75	0.5
Cotton	0.1	0.4	0.9	0.75	0.35
Fruit, deciduous	0.2	0.5	0.75	0.5	0.2
Fruit with cover	averages about 1.0 for all growth stages				
Grain sorghum	0.2	0.55	0.9	0.6	0.15
Grapes	0.15	0.2	0.55	0.35	0.2
Peanuts	0.15	0.35	0.6	0.6	0.3
Potatoes	0.2	0.45	0.9	0.95	0.9
Vegetable, deep rooted	0.2	0.25	0.65	0.45	0.2
Vegetable, shallow rooted	0.1	0.4	0.6	0.45	0.3

* The above figures to be multiplied by Class A pan evaporation (e.g. 0.7 from the standard constant factors above).

The efficiency of the type of irrigation system used must also be considered.

Irrigation system efficiency:

Sprinkler system	0.6 - 0.8
Surface system	0.3 - 0.8
Drip system	0.9 - 0.95

The above table provides an indication as to how well an irrigation system works. As can be seen, the drip system is by far the most efficient.

An example for irrigation calculations:

Crop: Corn
District: Gold Coast (Qld)

Irrigation system: sprinkler (i.e. Efficiency will be approx 0.75)

Soil: sandy loam

Transpiration rate = Evaporation rate x cf (Ea)

The evaporation rate for the Gold Coast in the month in which we are estimating irrigation requirements is 150mm (from meteorological data):

150 mm/month x 1 = 150mm per month

150 mm per month / 30 days = 5 mm per day

NETT Evaporation = 5 mm/day

If required: GROSS Evaporation = Nett day evaporation/ Irrigation Efficiency

= 5 mm day / 0.75

= 6.67 mm day Gross

Irrigation required per hectare = hectare x depth of water x L/m2

= 10,000 m2 x 0.005 x 1000 (conversion factor)

= 50,000 L/day

GROSS = 50,000 / 0.75

= 66,666 L/day

This is the minimum required to the plant crop each day

Average moisture in root zone = Root depth x Soil available moisture

= 1 m x 120mm (refer to Part 7 for root depths of particular crops).

= 120 mm

50% of this water will be available to plants before wilting begins (rule of thumb in the field) i.e. 60 mm is available to the plant.

Frequency of watering = 60 mm / 6.67 mm (gross evaporation figure from above)

= 9 days

(I.e. irrigation is required every 9 days to prevent wilting unless rainfall occurs).

For simplicity purposes, figures are rounded off.

That is, 60 mm required every 9 days.

To calculate flow required for a crop per hectare on a 9 day rotation:

(hectare x day period x litres required) / (day period x duration period to irrigate)

(10,000 m2 x 9 days x 0.06 L) / (9 days x 10 hour period to irrigate)

** note: we assume farmer wishes to irrigate for 10 hours during the night.*

= 60 m3/hour

= 60,000 L/hour

= 1000 L/minute

= 16.6 L/second

Note: There is a degree of human error in rounding off.

ESTIMATING WATER

The amount of water required by a plant is affected by many things including the following:

Type of Plant

Some plant varieties utilize more water than others.

Some plants have a greater resistance to dry conditions (e.g. cacti and succulents).

Rate of Growth

If a plant grows rapidly (perhaps because of its variety, or perhaps due to optimum growing conditions in terms of fertility, climate, etc.) it will use water at a faster rate.

Climate

In high temperatures soil loses water through evaporation.

In windy conditions both soil and leaves of the plant lose water faster.

Higher levels of natural rainfall reduce the need to irrigate. (Make sure you know not only what the annual rainfall is, but also what the distribution of rainfall is throughout the year).

Soil Conditions

- Does the soil drain freely?
- What is the soil's ability to retain water?
- Is there a hard pan or high water table below the soil surface?
- Does the soil repel water when dry (increasing surface run off)?

TABLE: Available Moisture in mm per 100 mm of Soil Depth

SOIL TYPE	***RANGE***	***AVERAGE (mm)***
Clay	2213	18
Clay loam	2012	16
Loam	1810	14
Sandy loam	128	10
Sand	87	7.5

From the above table you see that a loam soil holds approximately 14 mm of water per 100 mm of depth of soil. Hence: if the plant roots penetrate to a depth of 150 mm, 21 mm of moisture is available.

THE WATER NEEDS OF TURF GRASSES

Cool climate grasses rarely have underground stems therefore have no or little ability to move water horizontally within the sward. They have a higher water requirement than warm season grasses. From reports it has been noted that cool climate grasses need 60-65% of net evaporation loss to be replaced as irrigation to maintain a health turf.

Net Evaporation is equal to the evaporation from an open pan minus the rainfall in the same period

E.g. Net evaporation = Evaporation - Rainfall.

E.g. Net evaporation (obtained from Meteorological Bureaus

and many newspapers) for a week in summer = 90 mm

Rainfall for that week = 20 mm

Net evaporation for that week = 70 mm

Cool climate grasses would require 65% of 70 mm = 45.5 mm

Warm climate grasses would require 45% of 70 mm = 31.5 mm

As can be seen the amount of water needed by grass, or any plant, will change with climatic conditions. By estimating net evaporation figures, it may be possible to predict how much water the grass may need.

SET TASK

Activity 1

Visit a pump supplier and obtain friction loss charts/flow charts for a variety of pipes and pump performance charts.

Activity 2

Familiarise yourself with these charts.

Activity 3

If you have access to a pump system – try using the manufacturer’s chart and the calculations given in the lesson to find Static Head and Total Delivery Head.

Activity 4

Calculating flow rate: Students will need - 3 taps connected to water, a measuring container, a watch or timing device.

Calculate the flow rate for each tap using the calculation provided in the lesson.