Improving irrigation water use efficiency

Pipe hydraulics - some basics

Pressure

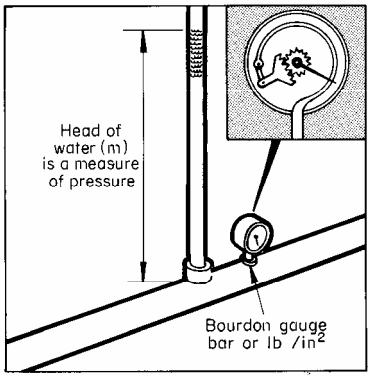
Pressure, in general terms, is a measure of the energy required to operate a sprinkler system. More specifically it is defined as a force acting uniformly over an area. Pipe and sprinkler irrigation manufacturers use many different and often confusing measures of pressure. Engineers in the UK tend to use the International System of measurement which means that pressure is measured in kilo-newtons per square metre (kN/m^2). This may be a strange measurement to most people and so the most common one used among irrigators is bar pressure. This is atmospheric pressure and so sprinkler pressures are expressed as some many bar pressure e.g. a raingun operates at 6 bar pressure.

Other common units of pressure are pounds per square inch (lb/in^2) which is an old Imperial unit, and kilogramme force per square centimetre (kg/cm^2) which is a European units.

Just to link all these measurements: – 1 bar is equal to $100kN/m^2$. It also equals $1kg/cm^2$ and is approximately $14.5lb/in^2$. A typical operating pressure for a small rotary sprinkler system is $300kN/m^2$ or 3bar ($44lbf/in^2$).

Measuring pressure

Pressure in a pipe system can be measured using a Bourdon gauge. Inside the gauge is a curved tube of oval section which tries to straighten out when the system is under pressure. The tube is linked to a pointer which moves across a graduated scale and records the pressure. Irrigators normally measure pressure in the field using these gauges as they are robust and simple to use. Frequently, however, engineers refer to pressure as a head of water as this is often more convenient for them. To understand this, imagine the Bourdon gauge is replaced by a long vertical pipe. Water pressure in the pipeline forces water to rise up the pipe and the height of the water column is a measure of the water pressure in the pipeline. For example, a pressure of 3bar on the Bourdon gauge would result in water rising to a height of 30m in the tube. This is rather a long tube and is not very practical as a measuring device but measuring pressure in metres head of water does have its uses.



It is simple to change from pressure to head of water.

Head of water (m) = 0.1 × Pressure (kN/m^2)
or = 10 × Pressure (bar)

In the old Imperial system of measurement a pressure of 45 lb/in^2 is equivalent to 104ft head of water.

Disclaimer: This information is provided as a reference tool only. It is issued as part of a Natural England Regional Farm Advice Programme workshop to help farmers in the East of England make practical and cost effective improvements in their irrigation efficiency and water resource management practices. Workshops organised by Cranfield University in conjunction with the NFU and supported by the UK Irrigation Association across the East of England

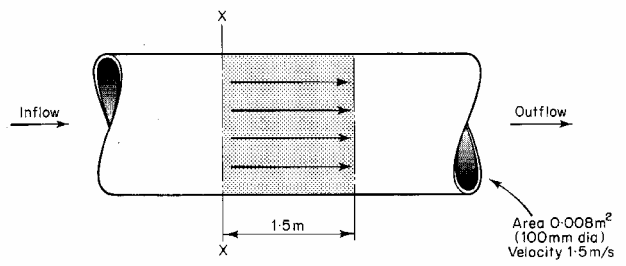
Discharge

The speed with which water flows in a pipe is called the **velocity** and this is measured in metres per second (m/s). **Discharge** is the volume of water flowing along the pipe each second which is measured in cubic metres per second (m^3/s). To understand this, consider the case of water flowing in a 100 mm diameter pipe (cross sectional area $0.008m^2$) at 1.5m/s. In one second the quantity of water flowing past x-x will be the shaded volume. The length of the shaded portion is numerically equal to the velocity, in this case 1.5m. The volume flowing each second – the discharge – is equal to the pipe area multiplied by the shaded length:

ie $1.5 \times 0.008 = 0.012m^3/s$.

In more general terms we can write:

Discharge (m^3/s) = cross sectional area of pipe (m^2) $\times$ velocity of flow (m/s)



For small sprinkler systems this unit of discharge is too small. An alternative is to use cubic metres per hour (m^3/h). In the example given $0.012m^3/s$ is equal to $43.2m^3/h$. The conversion is made by multiplying by 3600.

Measuring discharge

Discharge in a pipeline can be measured using a volumetric water meter. The meter indicates the volume of water passing through the pipeline. By noting time taken to do this the discharge calculated using:

$$\text{Discharge } (m^3/h) = \frac{\text{Volume of water } (m^3)}{\text{Time taken (h)}}$$

Discharge from a rotary sprinkler can be measured simply by connecting a flexible tube to the sprinkler nozzle and collecting a known volume of water in a container over a specified period. The discharge can then be calculated using the above formula.

Example

A small plastic tube is connected to a sprinkler nozzle and the discharge is collected in a bucket. The bucket can hold 5 litres of water and it takes 15 seconds to fill. Calculate the sprinkler discharge.

Volume of bucket = 5 litres = $0.005m^3$

$$\text{Discharge } (m^3/s) = \frac{\text{volume } (m^3)}{\text{time taken (s)}} = \frac{0.005}{15} = 0.00033\ m^3/s$$

This is a very small discharge. An alternative is to use m^3/h.

Discharge (m^3/h) = discharge (m^3/s) $\times$ 3600
= 0.00033×3600
= **$1.2\ m^3/h$**

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