ing insitutions and with your various organizations. On the one hand you need to tell the training institution what is required and on the other you need to ensure that those institutions get the staff, the finance, and the facilities to provide it.

HYDRAULIC ENGINEERING RELATIVE TO PLANT PROPAGATION

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1.0 INTRODUCTION

The basic aim of an irrigation system designer is to design a system capable of applying equal and even amounts of water in a controlled fashion to every plant within the system as required by the plant.

This aim is common to every system whether large or small. Such a system allows application of the optimum water requirement to each plant, thus optimizing production. The plant or plants depending on this system are usually of high value, when taken in terms of crop loss, lack of seed germination, reduced growth or replacement of the plants. Hence there needs to be a greater appreciation of system costs in relation to possible losses incurred by poor system performance.

In the practice of plant propagation the system becomes a part of the environmental control rather than solely an irrigation system. However many of the same principles of hydraulic design apply and the requirement for correct performance becomes of even greater importance.

Engineering technology today is sufficiently advanced to enable the development and installation of some very sophisticated irrigation systems but pure theoretical knowledge is not sufficient to guarantee optimum performance of the plant or plants. The designer must be made aware of the practical requirements of the system and the problems associated with operation, installation, and interaction with other cultural operations.

The user of an irrigation system is not required to have a detailed knowledge of the irrigation componentry and of irrigation system design. The most critical task which the user performs is the specification of the system which will suit his requirements and consequently he must either communicate this to the designer or manufacturer or select the equipment which will perform his specified task.

The object of this paper is to provide guidelines in preparing specifications and to give a basic understanding of design decisions.

2.0 SYSTEM TYPE AND LAYOUT

Systems used in plant propagation are basically mist or fog systems. Such systems differ from normal spray systems merely in the type of emitter used and in the operating pressures.

The system will comprise a water source which may be either mains or pumped supply, a main pipe to the control valve (or valves) and a distribution network of lateral pipes feeding to each emitter. To ensure optimum and equal performance from each emitting device the distribution network must be designed such that pressures are approximately equal over the whole network. The main itself must be capable of supplying the required quantity of water to the valves without unwanted loss of pressure or flow and the water source must be sufficient for all requirements.

3.0 EMITTER CHARACTERISTICS

3.1 Discharge Characteristics. The emitter will essentially be some form of misting (or fogging) jet. The unit may be merely a fan spray operated at very high pressures or a nozzle and deflector plate type.

Each type of misting unit is essentially an orifice with a pressure discharge characteristic defined by:

$$Q = Ca\sqrt{2gH}$$

where Q = flow through nozzle
a = cross sectional area
g = acceleration due to gravity
H = head pressure
C = nozzle constant

A plot of discharge versus pressure for any nozzle will take the form of the plot shown in Figure 1.

Note that nozzles become increasingly less sensitive to pressure variations as the pressure increases. This may be of benefit in limiting discharge variations between emitters but can also result in the need for increasingly larger pressures if application rates need to be increased. Such pressures may not be available from the source or may be uneconomic to maintain and hence it may be necessary to change to a larger nozzle.

3.2 Allowable pressure variations: Misting systems are usually controlled by some form of moisture sensing device placed at a discreet point within the system. The application levels at this point are assumed to be representative of the whole area covered

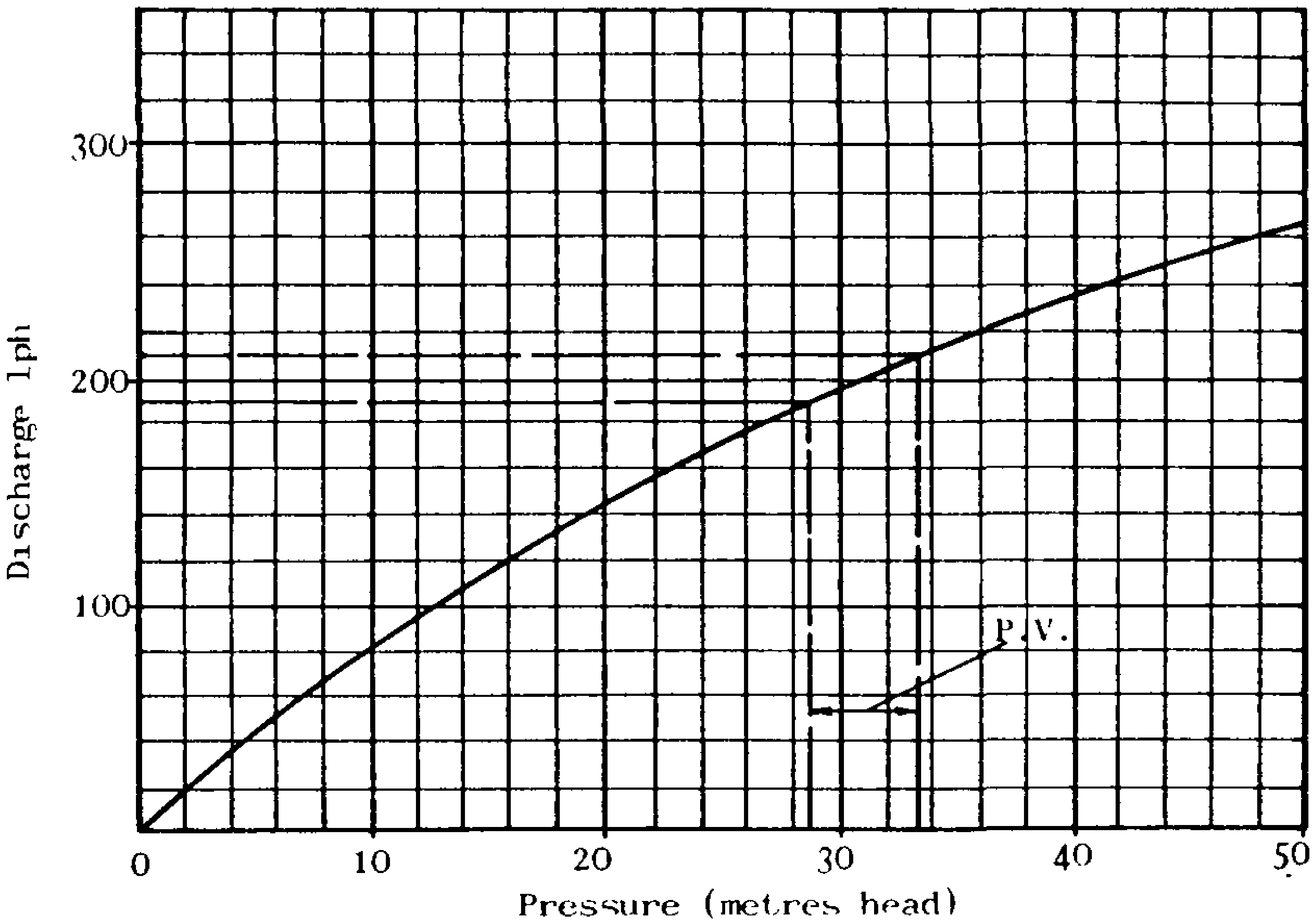

Figure 1. Discharge pressure curve for misting sprinkler

by the system so it is necessary to maintain nozzle discharges throughout the network at approximately equal rates to avoid net accumulations or declines in moisture levels at other points within the system.

Figure 1 shows a nominal operating pressure of 31.5 metres head and a nominal discharge of 200 l.p.h. If we are to assume that a discharge variation of ±5% is acceptable (from 190 to 210 lph) then pressures within the system must be maintained between 29 and 34 metres head for correct performance. Actual pressure discharge characteristic curves may be obtained from the manufacturer. Characteristic curves will vary depending on the type of emitter (due to variations in the nozzle constant C).

3.3 Diameter of throw — spacings. With normal sprays and sprinklers an increase in pressure results in an increase in diameter of throw. This is not necessarily true of a misting spray where increased pressures result in a smaller droplet size (and hence greater misting). It is possible that the diameter of coverage may even decrease slightly. Hence it is advisable to assume that the diameter of coverage of the sprinkler is constant over the operating pressure range and design the sprinkler spacings accordingly.

Misting sprinklers generally have a precipitation variation as shown in Figure 2. This is very approximate and will vary with type.

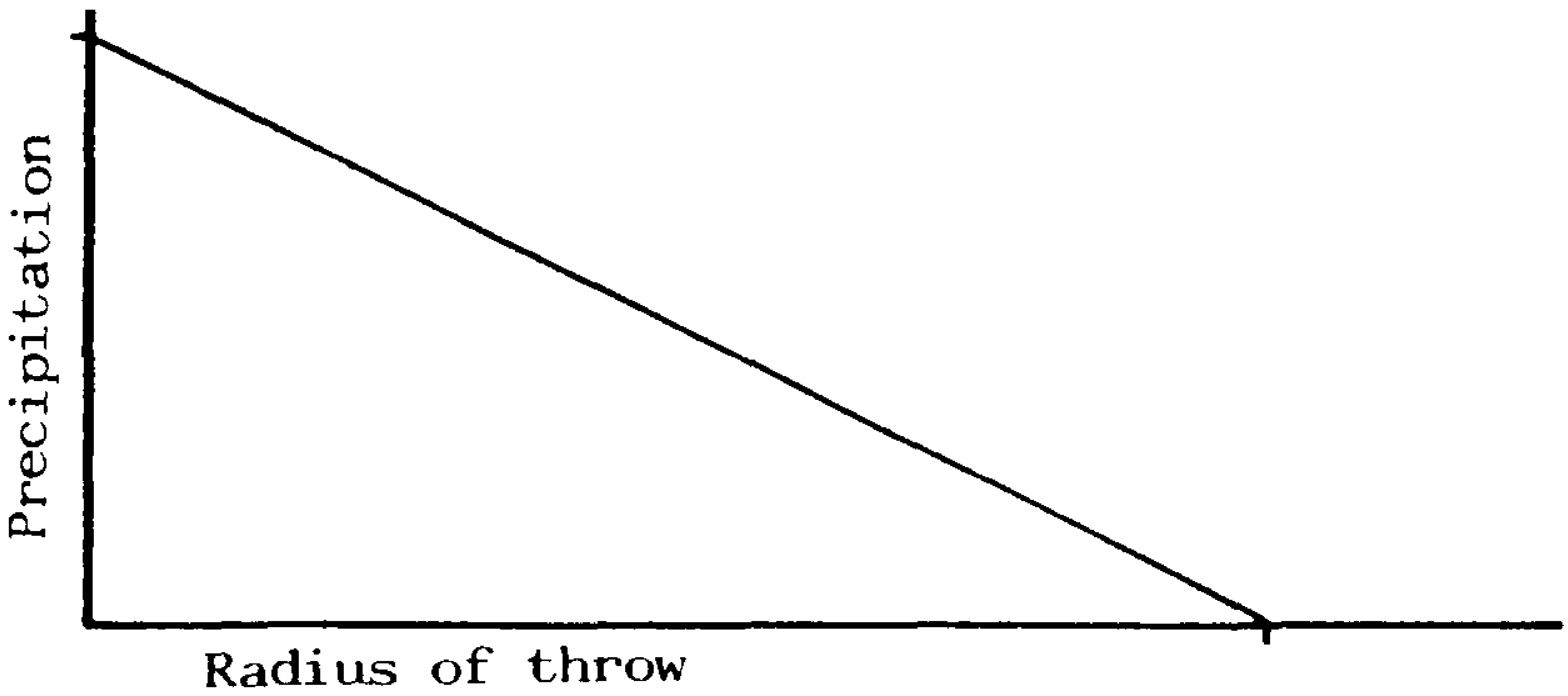

Figure 2. Relationship between precipitation rate and radius of throw.

The figure does indicate, however, that it is necessary to place the emitters at a spacing approximately equal to the radius for even application. It may be found necessary with some types of emitter to decrease the spacing even further.

In all cases a triangular placement of the nozzles will result in more even coverage if more than one run of sprinklers is necessary to cover the propagation beds.

4.0 HYDRAULIC DESIGN — PIPE DESIGN THEORY.

Pressure (or head) is lost in friction between the moving water and the wall of the pipe. Pressure is also lost in lifting the water up to a higher point (conversely pressure is gained in a downhill situation). The equations governing the flow of water are as follows:—

$$H_1 + Z_1 = H_2 + Z_2 + H_L \quad (1)$$

where H is the head (in metres or feet of water)

Z is the height of the point above some known datum (metres or feet)

H_L is the head loss due to friction incurred due to the flow of water between points (1) and (2)

The headloss due to friction may be calculated as follows —

$$H_L = f \frac{v^2 l}{2gd} = f \frac{8q^2 l}{g\pi^2 d^5} \quad (2)$$

where v = velocity of flow
l = length of pipe between points (1) and (2)
d = internal diameter of pipe
g = acceleration due to gravity (9 81 m/sec/sec)
q = flow
f = friction factor depending on the surface condition of the pipe

The friction loss for various flows for all types of pipes has been plotted in graphical form and produced by the manufacturers. However the formula (2) allows some pertinent observations to be made.

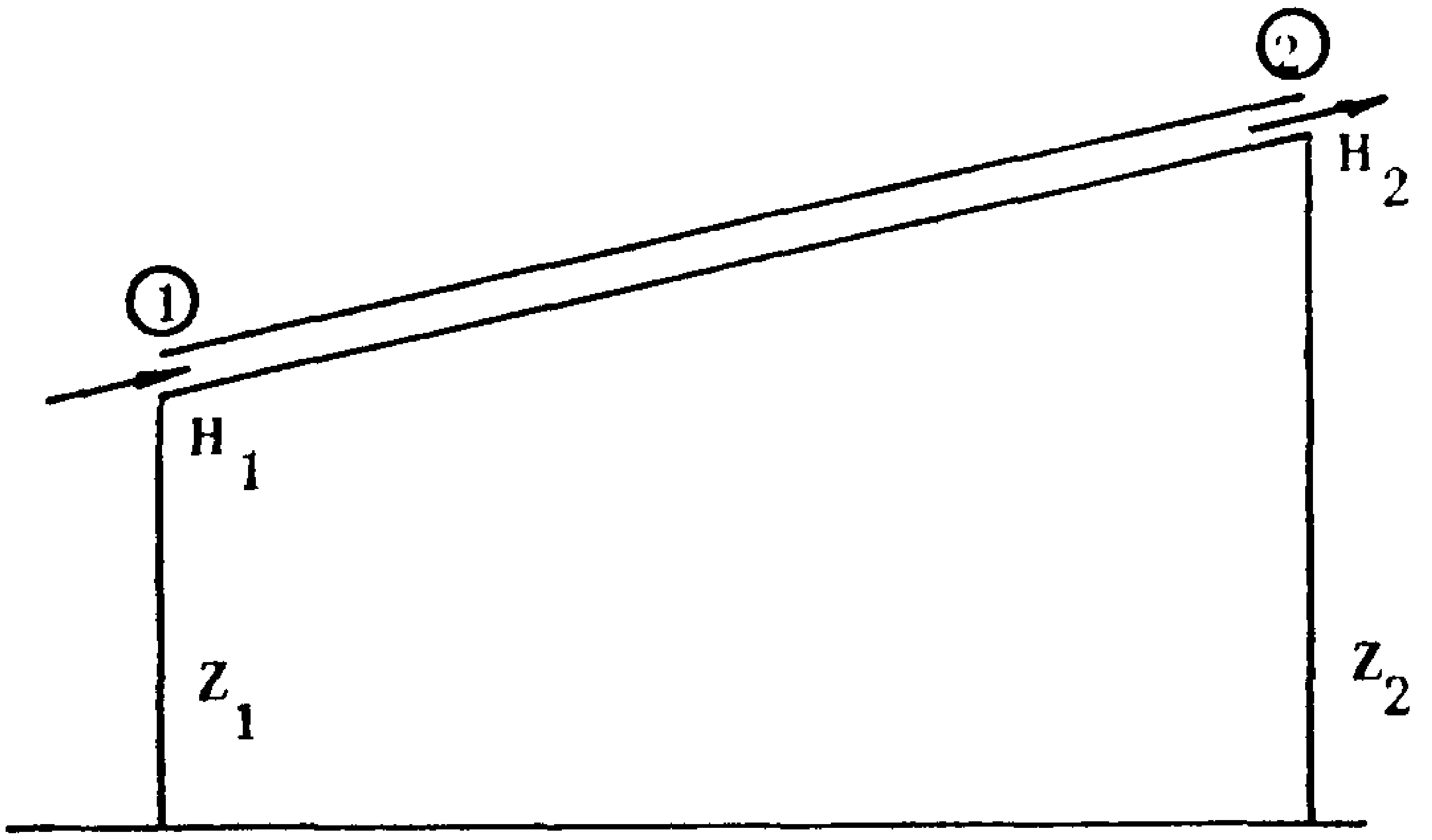

Figure 3. Pipe design formula

Increasing the length of the pipe will directly increase the pressure loss due to friction. Increasing the diameter of the pipe will decrease the pressure loss due to friction. Increasing the flow will increase the headloss due to friction.

Note that the headloss is dependent on the square of the flow. Thus doubling the flow will result in four times increase in the headloss.

Friction losses depend on the type of pipe used (Table 1), (i.e. variation in the friction factor f).

Table 1. Friction loss for various pipes with a flow of 2 5 lps (33 gpm) through nominal 50 mm (2″) Class 6 pipe

Material of manufacture	head loss (metres/1000 metres of pipe)
P V C pipe	21
High density poly tube	32
Asbestos cement pipe	37
Med galvanised iron pipe	48

The variation in headlosses as shown in Table 1 is due to differences in both roughness and internal diameter. For example, high density poly tube is as smooth as u P.V.C. pipe but the diameter is small (e.g. nominal 40 mm diameter H.D. poly tube has approximately the same internal diameter as nominal 32 mm diameter uP.V.C.) Note that the surface condition of the pipe becomes of great important where it is intended to use existing pipework. Increased friction losses may be incurred due to growth of material on the pipe walls. This is especially true of galvanised iron pipework.

5.0 HYDRAULIC DESIGN — DESIGN EXAMPLE

Sprinkler lateral design. As mentioned in Section 3.2 it is necessary to limit pressure variations within a lateral to the pressure variation as calculated from the discharge pressure characteristic curve. If we continue with the emitting device as indicated in Section 3.2 and assume that we have ten such nozzles spaced at 1.5 metre intervals along a 15 mm Class 15 P.V.C. pipe, what then is the pressure variation along the pipe? Pressure losses for the 15 mm PVC pipe are shown on the flow resistance chart with pressure losses shown in metres head/1000 metres of pipe.

Example Calculation. Nominal nozzle discharge 200 lph (0.056 lps):

flow lps	head loss metres/1000 m	actual head loss in 1.5 m pipe
0.056	—	—
0.11	16	0.024
0.17	34	0.051
0.22	54	0.081
0.28	86	0.129
0.33	110	0.165
0.39	145	0.218
0.44	245	0.368
0.56	275	0.413
TOTAL		1.71 metres

Note actual head loss is head loss per 1000 metres of pipe $\times \frac{1.5}{1000}$

From Section 3.2 the allowable head variation is from 29 to 34 metres head or 5 metres variation.

Hence, the above design is well within the tolerances dictated by allowable pressure variations.

5.2 Mainline design. Mainline design follows the same principles as applied in the previous design example with the additional factors that heights along the main may vary and that the flow will be constant over the length of the pipe.

In the design of the main the allowable pressure loss over the length of the pipe is the difference between that pressure available at the source and the pressure required at the controlling valve.

For this example we will extend the previous example and assume that three laterals are to be run at one time giving a total required flow of 1.7 lps. We will also assume that the water source is 120 m distant and provides a pressure of 50 metres. Assume a lift of 10 metres to the valves and note that the required operating pressure is to be 34 metres head from Section 3.2.

Example Calculation. Formula $H_1 + Z_1 = 8_2 + H_L$ (from Section 4.0)

H_1 = 50 metres head

$H_2 = 34$ metres head

$Z_2 - Z_1 = 10$ metres (the difference in height between points 1 & 2)

Hence

$$\begin{aligned} \text{The head loss } H_L &= H_1 - H_2 + (Z_2 - Z_1) \\ &= 50 - 34 - 10 \\ &= 6 \text{ metres head} \end{aligned}$$

For various sizes of pipe the head losses for a flow of *1.7 lps* may be calculated from the flow resistance chart:

Size of pipe	Head Loss metres/1000 m	Actual head loss over 120 metres
25mm Class 12	170	20 4
32 mm Class 9	58	7.0
40 mm Class 6	27	3 2

As the pressure losses in both the 25 mm and 32 mm main are above the allowable loss it would be necessary to select the 40 mm mains size.

6.0 ASSESSMENT OF WATER SOURCE

6.1 Type of Source. The source of the water may be either direct from mains or from a pumped supply. In a number of cases the latter system may be repumping mains water.

6.2 Mains Supply. The flow available from mains supplies will depend on the size of the meter available and the pressure in the mains network at the take-off point.

From our previous example to run these laterals at one time a flow of 1.7 lps was required. To achieve this from main it may be necessary to have up to a 32 mm water meter. However to run one lateral at any one time would require only a 20 mm meter.

To assess the suitability of the supply it is necessary to measure the pressure and flow available at the meter and to compare this with the flow required to operate the desired number of emitters. The appropriate government department may be of some assistance in establishing the performance characteristics of the metered or mains supply.

6.3 Pumped Supplies. In order to specify the characteristics of the pump required it is necessary again to establish the flow required. In addition the necessary pressure at the pump must be specified.

In the previous example (Section 5.2) a flow of 1.7 lps is required. The head pressure required is 51 metres if a 32 mm Class 9 main is used or 47.2 metres if a 40 mm Class 6 main is used. Such details may be forwarded to the pump manufacturer along with the suction condition. The manufacturer will then propose a pump capable of performing the required task.

7.0 ANCILLARY EQUIPMENT

7.1 Pressure Control. To achieve continuous optimum performance from a system, pressures must be maintained at the required level at all times. Where the input pressure from the source is constant (such as a pumped supply) pressures may be maintained merely by adjusting the valves at the head of the lateral.

Many systems are operated directly off mains, however, and pressures will fluctuate over a 24 hour period and from season to season depending on area usage. In this case some form of automatic pressure control is necessary and there are a number of different types of valves available which will achieve this. In specifying these valves it is necessary not only to give the required downstream pressure but to indicate the flows at which this pressure is to be achieved.

7.2 Automatic Control. The rapidly cyclic nature of mist propagation systems makes control by some form of automatic sensor a necessity. While it is not within the scope of this paper to enter into discussion on the forms of control available most systems operate an electric solenoid valve to turn on the water.

Electric solenoid valves operate by use of a pressure differential and spring force on a diaphragm within the bonnet of the valve. Various types have differing opening and closure speeds. This must be established empirically. It is, however, unwise to use a valve with a very high opening or closure speed especially in high pressure systems as the resulting water hammer may cause pipe damage

It is necessary to ensure that the valve is of sufficient size to pass the required water flow without incurring undue pressure loss. It may also be necessary to ensure that the valve is fitted with manual flow control so that operating pressures may be set at the required level.

7.3 Filtration. Mist propagating systems utilise emitters with a very small orifice. It is essential to ensure that water sanitation is at a high level so that plugging of emitters does not occur. Where inorganic material is the expected blocking agent a screen filter may be used. It is recommended however that a screen with a mesh opening size of ⅓ of the orifice size be used.

Note that mains water will also require filtration to this level. Where organic material can be expected it is usually necessary to incorporate some form of sand filtration into the system using sand of between 10-25 particle size.

Note that as with all fittings, valves, etc. within the water flow, pressure losses will be incurred across the filter. When allowing for available pressure at the supply it is necessary to incorporate the pressure loss across the filter in the dirty condition, not the clean loss.

COLLECTION AND TRANSPORTATION OF FIELD CUTTINGS

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The first task in preparing for a field trip is to organize efficient insulation of the vehicle floor.

In our climate, the transfer of temperature through the chassis and vehicle floor frequently raises the floor temperature above tolerable levels. It has been found that a false floor of pressed packs available for seedlings, is excellent insulation.

MATERIALS REQUIRED FOR LENGTHY FIELD TRIPS ARE AS FOLLOWS:

1. Large "poly" boxes with efficient self-sealing lids.
2. A large quantity of paper (Butcher's paper for the purist — newsprint for the rest).
3. A plentiful supply of water, preferably carried in small, easily handled square containers of 4 to 5 litre capacity.
4. A squeeze pack or hand operated vaporiser.
5. Medium sized clear plastic bags plus some hessian or woven plastic bags.
6. Sphagnum moss.
7. A quantity of unexpanded cardboard cartons and appropriate tapes and ties.
8. A substantial piece of shade cloth which may be rigged to cope with direction shifts and sun intrusion.

TAKING CUTTINGS

Wherever possible the material should be collected shortly after daylight.

The material should be partially reduced immediately and wrapped in moist paper before stowing in a "poly" box, or into a cardboard carton.

At night camp, further reduction may be made but never to the prepared cutting stage.

Advantage should always be taken of night temperatures and possible dew. However, material should be protected from winds.