Training material for extension advisors in irrigation water management

Volume 2: Technical Learner Guide
Part 5: Irrigation engineering

JB Stevens, F Buys & S Smal

TT 540/5/12

WATER RESEARCH COMMISSION

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Report to the

Water Research Commission

University of Pretoria

NQF
Level 5

WATER RESEARCH COMMISSION

agriculture, forestry & fisheries
Department: Agriculture, Forestry and Fisheries
REPUBLIC OF SOUTH AFRICA

WRC REPORT NO. TT 540/5/12

OCTOBER 2012

OBTAINABLE FROM

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The publication of this report emanates from a project titled *Development of training material for extension in water irrigation management* (WRC Report No. K5/1649).

This report forms part of the following set of reports:
Volume 1: Main report
Volume 2: Technical learner guide
Volume 3: Extension learner guide

ISBN 978-1-4312-0340-6
Printed in the Republic of South Africa

Acknowledgements

The project team is grateful to the Water Research Commission (WRC) for initiating, soliciting, funding and managing of this very important project. The financial contribution by the Department of Agriculture, Forestry and Fisheries is also acknowledged. The following members of the Reference Committee are thanked for their valuable and significant guidance and support during the project:

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Mr JLH Williams	Private Consultant

The project team expresses its profound gratitude to:

- Extensionists of the provincial departments of Limpopo, Northwest, Mpumalanga, KwaZulu-Natal, Eastern Cape, Free State and Northern Cape
- Lecturers of agricultural colleges and universities of technology for participating in the discussion forums and testing of learning material.
- *Advisors and technical/extension experts:*

  Mr Andre vd Merwe, Transvaal Suiker Beperk

  Mr Francois Marais, Elsenburg Agricultural College

  Prof Chris du Preez, University of the Free State

  Prof Sue Walker, University of the Free State

  Dr Baldur Koch, Private Consultant

  Mr Chris Barnard, Fertigation Academy

  Mr Francois vd Merwe, Department of Water Affairs

  Mr Abraham Bekker, GWK

  Mr Amos Montjane, Tompi Seleka Development Institute

Mr Piet du Toit, Private Consultant

Mr Gerhard de Kock, Private Consultant

Mr Johan van Stryp, Loskop Irrigation Board

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Dr Fanie Terblanche, University of Pretoria

Dr PG Strauss, SAB

Mr Dieter Jordaan, Northwest Department of Agriculture

Cabeton Training and Development

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Mr Eckardt Hagedorn, Private Consultant

Dr Andries Liebenberg, ARC Summer Grain Centre

Dr Andre Nel, ARC Summer Grain Centre

Dr Hennie le Roux, Citrus Research Institute

Mr Francois Olivier, SASRI

Mr Wouter Retief, SUBTROP

Various researchers from ARC Roodeplaat Vegetable and Ornamental Plant Institute

Potato South Africa

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Before we start...............

Dear Learner ....this learner Guide contains information to acquire the basic knowledge and skills leading to the unit standard:

Title: Monitor the operation and maintenance of irrigation systems

US No: 116266 **NQF Level : 3**

Title: Manage water quality parameters

US No: 116322 **NQF Level : 4**

Title: Schedule the operation and maintenance of irrigation

US No: 116322 **NQF Level : 4**

The full unit standards are available and can be cited on the SAQA website. Read the unit standards at your own time and if there are any questions or aspects that you do not understand, discuss it with your facilitator.

The unit standards are some of the building blocks in the qualification listed below:

Title	**ID no**	**NQF Level**	**Credits**
National Diploma: Plant Production	49010	5	120
National Certificate: Plant Production	49009	4	120
National Certificate: Plant Production	49052	3	120

Assessment.........

You will be assessed during the course of the study (formative assessment) through the expected activities that you are expected to do during the course of the study. At the completion of the unit standard, you will be assessed again (summative assessment).

Assessment therefore takes place at different intervals of the learning process and includes various activities - some will be done before commencement of the program, others during the delivery of the program and others after completion of the program.

How to attend to the activities.......

The activities included in the module should be handed in from time to time on request of the facilitator for the following purposes:

- The activities that are included are designed to help gain the necessary skills, knowledge and attitudes that you as the learner needs in order to become competent in this learning module.
- It is important that you complete all the activities and worksheets, as directed in the learner guide and at the time indicated by the facilitator.
- It is important that you ask questions and participate as much as possible in order to be actively involved in the learning experience.
- When you have completed the activities and worksheets, hand it in so that the assessor can mark it and guide you in areas where additional learning might be required.
- Please do not move to the next activity or step in the assessment process until you have received feedback from the assessor.
- The facilitator will identify from time to time additional information to complete. Please complete these activities.
- Important is that all activities, tasks, worksheets which were assessed must be kept as it becomes part of your Portfolio of Evidence for final assessment.

Check your progress.......

Use the following checklist to determine your competency regarding this specific learning module.

Confidence level	I am sure	Still unsure	Do not understand and need help	Motivate your answer
Can you identify problems and troubleshoot correctly?				
Are you able to work well in a team?				
Are you able to collect the correct and appropriate information required for decision making?				
Will you be able to perform the observation expected in an organised and systematic way while performing your task as an extensionist?				
Are you able to communicate the information and newly gained knowledge well to experts?				
Can you base your tasks and answers on scientific knowledge that you have learned?				
Are you able to show and perform the activities required in this learning module correctly				
Are you able to link the knowledge, skills and competencies you have learned in this module of learning to specific duties in your job?				

How to use this guide ………….

Throughout the learner Guide you will come across certain re-occurring notifications. These notifications each presents a certain aspect of the learning process, containing information, which would help you with the identification and understanding of these aspects. The following will be found in the learning material:

Study objective	What are the study objectives for a specific module? This provides an idea of the knowledge, skills and competencies that are envisaged to be
Activity	You will be requested to complete activities, which could either be group or individual activities. Please remember that the completion of these activities is important for the facilitator to assess, as it will become part of your ***Portfolio of Evidence.***
Definition	What does it mean? Each learning field is characterised by unique terminology and concepts. Definitions help to understand these terminology and concepts and to use it correctly. These terminology and concepts are highlighted throughout the learner guide in this manner.

My notes……………………………

You can use this box to jot down some questions or notes you might have, concepts or words you do not understand, explanations by facilitators or any other remark that will help you to understand the work better.

What are we going to learn?

For each of the learning modules included in this learning area specific learning outcomes were set, which you need to be able to demonstrate a basic knowledge and understanding of.

Contents

Module 1

Maintenance of pumps, pipes, valves and filter systems for efficient irrigation

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- Layout of a pump station
- Best management practices for the operation of pumps
- Troubleshooting of pump functioning
- Electric motors as a source of energy supply
- Different tariff options for the use of electricity by irrigation farmers
- Various types of pipes used for conveyance of irrigation water from the source to the field
- How to troubleshoot for uPVC pipes?
- How to troubleshoot for LDPE and HDPE pipes?
- Different quick coupling irrigation pipes
- Troubleshooting of pressure relief and pressure sustained valves
- Troubleshooting of pressure reducing valves
- Troubleshooting of electrical control valves
- Troubleshooting of sluice valves
- Different types of filtration systems for efficient irrigation
- To clean filters
- Management of a filter system

Table of contents

The maintenance of an irrigation system is very important and this module aims to present the major aspects to take into consideration with the management and maintenance of pumps, pipe, valves and filter systems as effectively as possible. A lack of maintenance of any of these components of the irrigation system usually results in a decreased performance like the occurring of blockage in the irrigation system which results in a lower uniformity; reduced flow rates and higher friction losses.

A complete set of guideline on maintenance of in-field irrigation systems are found in the ARC IAEs Irrigation User Manual and from the various manufacturers of irrigation products.

1. Guidelines for the operation and maintenance of pump stations

The most efficient on-farm conveyance system is the one that is maintained according to the manufacturers' recommendations. Regular maintenance (routine and emergency) will reduce operating costs and unnecessary water losses.

a. Guidelines with the lay-out of a pump station for river abstractions

Extraction points for pumps where erosion of riverbanks occur must be avoided. The extraction point must preferably be at a point where the river flow is straight. The directives for the minimum required water depth and maximum permissible flow speed, as described in Section 6 of the Irrigation Users' Manual must be maintained. If the water depth is insufficient, a reservoir must be built next to the riverbank. The pumps must be installed in the reservoir. It is important that the $NPSH_{required}$ by the pump is at all times smaller than the $NPSH_{available}$ on the site (see Module 6). Problems with pumping from a river can be solved in one of the following ways:

- Pumps with multi-impellers and low rotation speed (1450 rpm) with good suction ability, can be used. Alternatively, a light pump with good suction ability (that can be moved manually and will not cost too much to replace) can be used down by the river, supplying to the main pump that is situated on top of the dam wall, away from the danger zone.
- Mount the pump on a rail and drag it out of the danger zone when necessary. Quick-coupling delivery pipes, and sometimes a windlass, are necessary here.
- Mount the pump on a frame 4 to 5 times higher than the water level; drive the pump with V-belts with the motor or engine above the floodplain.
- Build a reservoir next to the riverbank. Mount pipes in the reservoir. Ensure that the river does not rise to the reservoir. Install hoisting scaffoldings to raise or remove the pumps. Use submersible pumps for pumping the water to the reservoir.
- Pumps on floats on the river: A typical float consists of 12 plastic drums of 200ℓ used for fire fighting. The drums must be filled with polystyrene that will keep them from sinking, even if they are broken. A float with a sharp edge, such as the prow of a boat, will form a vortex under the float. This keeps silt away from the extraction point. A sieve box can be mounted underneath the float, from which the water is extracted. Holes, preferably larger than 10 mm will let the water through. This combination is ideal for good water flow through the box without leaves and branches being sucked in and blocking it. The float must be able to withstand a rise in the river water when the river is in flood. Scaffolding similar to cantilevers can also keep pumps close to the water level and can then be lifted by means of windlasses (hoists) in case of floods.

Note: *When pumping from a river, it is important to remember that fish is sensitive to horizontal water speed. Therefore, to keep them out of the inlet of the suction pipe, the structure around the suction pipe must be built as such that the water flows horizontally at a low speed (0,15 m/s maximum), so that the fish can escape.*

b. Best management practices for the operation of pumps

1. Before starting up

i. De-aeration ("priming")

In order for a centrifugal pump to work, all air must be removed from the pump casing and suction side pipe work before starting the pump, by filling the pump casing and suction pipe with water before the pump is switched on.

De-aeration can be done in four different ways:

- *Vacuum pump*

A manual pump is installed on the pump casing, which pumps out all the air each time the pump is to be used.

- *Foot valves*

It is a one-way valve installed on the inlet of the suction pipe, which prevents the water from the pump from draining out of the suction pipe as soon as the pump is switched off. However, foot valves clog easily, with consequent high friction losses, and they are seldom totally dependable.

- *Priming from supply pipe*

A pipe is installed in the supply pipe on the downstream side of the valve and it is attached to the pump casing. The pipe line is also provided with a valve and the pump is then primed by opening this valve to displace the air in the pump casing and suction pipe with the water in the supply pipe.

- *Positive inlet*

The pump is installed in the pump sump at a lower level than the water level, which ensures that there will always be water in the pump casing and suction pipe. This is the ideal, but not always possible. Problems with NPSH are also ruled out in this way.

ii. Check Alignment

Before starting the pump, first check the alignment. Ensure that all the rotating parts are free by turning them manually (if possible).

iii. Rotation direction

Check the direction of rotation as indicated on the pump, and confirm when pump is running. Inspect all wearing parts regularly.

iv. Lubricants

Check the oil levels in oil-lubricated pumps. Greased pumps must be checked for excessive grease. Replace the oil every six months if applicable. Some pumps and motors have sealed bearings which require no greasing – confirm with supplier or manufacturer.

2. Steps for starting up

i. **Check voltage**. In case of 3-phase motors the supply voltage should be 380V. The reading on the volt meter usually indicates around 400V.

ii. **Priming**. Ensure that the suction pipe is filled (no air) as discussed in 1.2.1 under De-aeration.

iii. **Close main valve**. Check that main valve is closed for starting. The reason therefore is that when the pump is not switched on at closed valve, it then pumps at a low pump head with high pumping volume that can lead to electric current overloading and even damage to the motor. If ESKOM power is used, it will also keep the kVA demand low.

iv. **Start pump** only when all is clear, and ensure that it is running in the right direction.

v. **Open valve.** As soon as the pump runs at full speed and the required pump head is reached, the main valve can be opened slowly. **Check** the reading on the **ampere meter** to ensure that the permissible value is not exceeded. If opened too quickly, the pump may start cavitating (making loud cracking noise) because of vacuum forming inside impeller due to over pumping.

vi. **Check pressure gauge** to ensure that the correct pressure is generated and delivered. In most cases the amp meter and pressure gauge are always at a constant level (if the pump delivers a constant volume to a specific system).

vii. **Check noise and vibration.** If abnormal noise levels or vibration are experienced the pump should be shut down immediately. Troubleshooting should be done to find the problem.

viii. **Check pump seal** (gland packing). During commencement of operation, note the quantity of water leaking at the pump gland. If excessive leaking occurs, the gland nuts must be tightened slowly and evenly on both sides until the water just drips slowly. Ensure however that the pump gland is not tightened too much, because it can lead to heat build-up that can damage the pump shaft.

Note: *The pump must not be allowed to operate at closed valve for too long, since overheating can occur.*

Where a number of pumps are served from one transformer, it is also important to switch on the pumps in order of large to small. It also keeps the kVA electricity demand peak low.

3. Switching off

It is advisable to slowly close the sluice valve on the delivery side of the pump just before switching off the pump, because it prevents water hammer and will also keep water in the pipes that can possibly be used for the next de-aeration of the pump. Also close the small valve that closes off the vacuum meter on the suction side before the pump is switched off (if applicable).

4. Pump maintenance

The pump manufacturer usually provides a maintenance schedule that indicates the maintenance to be done. As with any type of equipment, it is very important that the necessary maintenance is done regularly to ensure that the installation can function efficiently and that the life span of the installation is prolonged. The pump must always run smoothly without any vibrations. The water depth on the suction side as well as the power consumption must also be regularly monitored.

The following can serve as directives for the maintenance of the centrifugal pumps:

- Check the alignment every six months.

- Pumps are lubricated by oil or grease, and this needs to be checked regularly. Oil lubricated pumps have a dipstick similar to motor engines, and should be filled only according to the markings. Greased bearings need regular (monthly) greasing, but care should be taken not to overfill the grease chamber and pressurize the grease, as it will warm up under pressure and damage the bearing. Replace the oil when it becomes contaminated (not clear). If the oil level drops, new oil must be added. [SAE 30 or as specified]

- Inspect all wearing parts regularly and do a simple pressure test by just closing the sluice valve and taking a reading on the pressure meter that is installed upstream of the sluice valve. If the pressure drops significantly in relation to when the pump was initially installed, it indicates excessive wear on the impeller. If the pressure drop is not acceptable, the impeller (or pump) should be replaced. This test should be sufficient for maintenance purposes. By monitoring the ampere reading, it can also be determined whether the pump's service point (flow and pressure) changes with time.

- Inspect the gland (mechanical) seal regularly. It must leak slightly, because the shaft is lubricated and cooled by water. Also feel the pump for excessive vibration.

Table 1. Pump troubleshooting[8)]

Problem	Possible causes	Solution
Pump does not deliver water	Pump is not sufficiently de-aerated. Air is trapped in suction pipe	Switch off pump and de-aerate thoroughly
	Air leaks into suction pipe or pump stuffing box (packing)	Repair leaks or replace packing
	Impeller turns wrong direction	Change rotation
	Pump does not run on speed	Increase rotation speed
	Impeller eye too high above water level	Mount pump closer to water level.

Problem	Possible causes	Solution
Pump does not deliver the correct amount of water and /or pressure	Impeller damaged or blocked	Dismantle pump and replace impeller
	Pump does not run on speed	Increase speed
	Foot valve or sieve in front of suction pipe inlet blocked	Clean foot valve or sieve
	Suction pipe not deep enough under water	Ensure suction pipe is deep enough under water surface.
	Invisible leakages in pipe lines	Inspect pipe lines for leakages – repair.
	Excess wear of seals	Dismantle pump and repair
	Pump gasket leaks	Replace gasket
	Blockage in impeller or pump casing	Open casing and clean impeller
	Pump head overestimated	Test friction losses in pipes, bends, reducers and valves
	Obstruction in delivery pipe or incorrect pipe diameter	Clean delivery pipe or install correct diameter delivery pipe
	Air leaks into suction line or stuffing box	Repair leaks or re-pack stuffing box
	Air accumulation at high points	Lower pump
	Impeller turns wrong direction	Change rotation
Pump loses water after switch-on	NPSH not sufficient	Lower pump
	Air leaks into suction line or gaskets	Repair leakages or replace gaskets
	Suction pipe inlet not deep enough under water	Ensure there is enough water in pump sump and suction is deep enough under water
	Liquid seal after stuffing box choked	Clean seal
Pump vibrates excessively or generates excessive noise	Pump and motor incorrectly aligned	Realign pump and motor
	Impeller damaged or blocked	Dismantle pump, replace or clean impeller
	Electric motor or shaft imbalanced	Check shaft balance
	Coupling damaged	Repair coupling
	Worn or loose bearings	Dismantle pump and replace bearings
	NPSH exceeded	Lower pump
	Pump shaft bent	Replace or repair shaft

Problem	Possible causes	Solution
Pump uses excessive power (Amps)	Serious leakage in delivery pipe	Repair leak
	Speed too high	Correct rotation speed
	Internal components of pump too tight	Dismantle pump and test clearances – adjust
	Impeller neck rings excessively worn	Dismantle pump and repair
	Pump bearings defective	Replace bearings and inspect lubrication
Bearings overheat	Pump and motor incorrectly aligned	Realign pump and motor
	Oil level too low or too high	Fill up or drain to correct level
	Wrong grade of oil	Drain oil, rinse and refill with correct oil grade
	Bearings too tight	Ensure correct positioning and spacing of bearings
Varying pump delivery	Air leaks into suction line or stuffing box	Repair leakages or re-pack stuffing box
	Suction pipe inlet not deep enough under water	Ensure suction deep enough under water
	Air trapped in suction pipe	Switch off pump and de-aerate thoroughly

In case of dismantling the pump, the following should be inspected and noted:

- Impeller clearance at collar – skim the impeller neck to give clearance and mount the correct wear rings.
- Inspect the pump shaft for damage
- Check impeller for damage – from inlet as well as in veins
- Replace bearings if necessary
- Clean surfaces of impellers, pump casing, etc. – paint casing if necessary.
- Replace gaskets and o-rings
- Check all adaptor pieces.

Table 2. Maintenance schedule for pumps[5)]

Monitor	Monthly	1 000 operating hours	Bi annually	Annually
Check alignment /settings			•	
Replace oil			•	
Inspect bearing and clean		•		
Inspect all parts for wear and to do hydraulic test*	•			
Inspect the gland packing leakage (it must leak slightly, because it is lubricated by water)	•			
Replace the gland packing				•
Inspect cables and electric equipment			•	

2. Electrical motors as source of energy supply

The type of power sources being considered for irrigation, mainly includes electric motors, and to a lesser extent, internal combustion (petrol or diesel) engines. The choice between these two main types of drive systems is usually based on economic but also on practical considerations. The cost of electricity in proportion to that of fuel for an internal combustion engine is such that electricity is usually preferred, except where the cost of supplying electricity to a specific point is very high.

Electric motors are consequently usually preferred to internal combustion engines and internal combustion engines are normally only used where three-phase power is unavailable, variable speed is required (which is very unlikely), or where the pump has to be portable. It is, however, also possible to make use of an electric motor for portable pumps, but then every pump station has to be provided with a three-phase power supply.

The standard direction of rotation of the shaft of an electric motor is clockwise if you look at the driving-shaft side of an electric motor. It concurs with the desired direction of rotation for centrifugal pumps. It is, however, possible to change the direction of rotation by changing the connection of the supply current. This must, however, be entrusted to a qualified electrician.

2.1 Cooling

Although heat loss also means a loss of energy, the motor has to be cooled to prevent it from overheating and thus being damaged. The IC code in accordance with SABS 948 (revised), IEC 34-6 and BS 4999/21 indicate the method of cooling. Of these, the TEFC motor (totally enclosed fan cooled) is the most well known. The most common methods are the following (Table 3).

Table 3. Cooling methods[2)]

Code	Type of cooling	Common name
IC 01	External air is sucked in from outside the motor and blown out again	Drip proof
IC 01 41	Two separate airflow paths. External air flows freely over external surface areas of motor's body. Internal air flows freely over internal surface area of motor.	Totally enclosed fan cooled
IC 00 41	No forced external cooling. Internal air flows over internal surface area of motor	Totally enclosed
IC 01 61	Two separate flow-paths by heat exchanger mounted on top of motor. External and internal air circulated through heat exchanger.	Closed air circuit air

To ensure that effective cooling of the motor takes place, the ventilation within the pump house is also very important.

2.2 Protection

Electric motors are manufactured to offer a certain standard of protection against live and moving parts, foreign objects and water. The IP code is used to indicate this protection. The code consists of IP, followed by two figures. From this it can be seen that IP44 offers protection against contact with delicate tools and the entrance of solid objects larger than 1 mm, as well as against water splashing from any direction. IP 22, IP 44, IP 54 and IP 55 are the most common. Standard electric motors are manufactured for IP 44 protection, although certain manufacturers prefer IP 55.

2. 3 Power rating

The power rating of an electric motor is its mechanical output capacity or rate of performance. Every electric motor has a certain maximum power, which it is able to deliver. This is known as its power rating and it is thus a characteristic of a specific motor and that is why we refer to a 15 kW or a 22 kW motor. The series of power ratings of electric motors are standard. The standard power rating for three-phase electric motors (probably used for the powering of irrigation pumps), are indicated in Table 4.

Table 4. Standard power ratings of some electric motors [kW][2)]

0,75	3,0	11,0	30	75	160
1,1	4,0	15,0	37	90	185
1,5	5,5	18,5	45	110	200
2,2	7,5	22,0	55	132	220

The power rating of an electric motor is also influenced by the ambient temperature and the height above sea level, and has to be corrected during design.

2.4 Supply cables

Cable design and selections are usually done to conform to SABS 0142-1981, Regulation 4.3.4. This regulation dictates that the maximum voltage drop under full-load conditions may not exceed 5%. It boils down to 19 V between phase and phase and 11 V between phase and neutral if the voltage is 380 V. The cable size must, however, be based on the voltage drop [ΔV] of 5% maximum between phase and neutral, i.e. 5% of 220 V = 11 V.

2. 5 Couplings

If the cable size is too small, the voltage [V] decreases and this causes the electric motor to draw a higher current. The motor may thus overheat sooner than expected and the energy loss will also increase. It is thus very important not to use cables that are too small.

The type of coupling, direct or belt and pulley, is mainly determined by the speed of the driver vs. the speed at which the pump must run. If it is equal, direct coupling will probably be the proper method to follow. If not, belt and pulley coupling should be used.

Table 5. Trouble shooting for electric motors [8)]

Problem	Possible causes	Solutions
Bearings overheat	Pump and motor incorrectly aligned.	Realign pump and motor.
	Oil level too low or too high.	Fill up or drain to correct level.
	Wrong grade of oil.	Drain oil, rinse and refill with correct grade of oil.
	Bearings too tight.	Ensure that bearings are correctly installed, replace if necessary.
Excessive vibration	Pump and motor incorrectly aligned.	Realign pump and motor.
	Worn or loose bearings.	Dismantle motor and replace bearings.
	Shaft is bent.	Dismantle motor, straighten or replace shaft. Replace bearings if necessary.
	Foundation not firm.	Remove motor, strengthen foundation, re-install motor.
	Coupling damaged.	Replace coupling.

Problem	Possible causes	Solution
Motor overheats	Power delivery of motor too low for application.	Check design and replace if necessary.
	Cooling fins or fan choked.	Remove fan cover and cooling fins. With standard motors, it may be necessary to dismantle the entire motor.
	Radiator system faulty or dirty or incoming water too warm.	Inspect system, clean heat exchanger and provide water at correct temperature.
	Ampere too high as result of low voltage (volts).	Test voltage and repair if necessary.
	Ventilation in pump chamber insufficient.	Inspect and improve if necessary.
Motor won't start	Switchgear faulty.	Inspect and improve if necessary.
	Motor incorrectly connected.	Test connections against diagram.
	Supply current does not reach motor.	Inspect and correct.
	Connections faulty or cable broken.	Tightens connections, clean and test cable.
Motor switches on but won't take load	Overloads set incorrectly.	Check and rectify.
	Supply current too low.	Test and rectify.
	Loose connections in system.	Test and rectify.
	Motor too small for application.	Test and replace if necessary.
	Starting method incorrect.	Test design and replace if necessary.
	Wrong choice of motor.	Check motor and rectify.
	Bearings too tight.	Test and rectify.
	Turning direction incorrect.	Test and rectify.
Motor's windings burn out	Overloading mechanism set too high or motor too small for application.	Check adjustments and design.
	Type of insulation not suitable for application.	Test suitability of design, replace with correct type of motor if necessary.
	Moisture penetrates windings.	Look for place where moisture penetrates and seal and replace windings.
	Design of motor not suitable for application.	Test suitability of design, replace with correct type of motor if necessary.

2.6 Tariff structures

Energy costs play a very important role in the economic viability of a pump installation. In most areas, ESKOM is the only supplier of electricity, while diesel engines are normally used where electricity is unavailable. Pumping water with diesel power is however up to 10 times as expensive as using electricity. Irrigation farmers have very little influence over the electricity tariffs or the reliability of supply.

For rural users ESKOM has three tariff options for the supply of electricity. These are NIGHTSAVE Rural, RURAFLEX, and LANDRATE. Where a farmer chooses to mainly us the night rate options, the designing of the irrigation system should be adapted to operate within these hours, even during peak irrigation periods. This often requires that the capacity of the irrigation system should be increased in comparison to a system that operates over a full 24 hour period (usually implies bigger pipes, pumps, and system components). More detailed discussion on the various options is available in Module 5 of Chapter 4. For more information on the various tariff options and current charges visit the ESKOM website, www.eskom.co.za

3. Pipes and pipelines

3.1 Steel pipes

Compared to other pipes, steel pipes are relatively costly for smaller diameters but work out more economically for large diameters. The high costs and scope of projects where large steel pipes are used usually require the expertise of a professional engineer who carries full responsibility for the design.

Corrosion protection is of great importance with steel pipes. The following methods of protection are generally used:

- Galvanizing
- Epoxy
- Bitumen
- Protective wrapping, especially at joints
- Electrolytic protection

While galvanized pipes are generally rustproof, problems sometimes occur with soft water. Bacteria, which attack the galvanizing, are also present in some soils. Epoxy coating generally provides good protection but tends to wear and chip with careless handling. Bitumen tends to become brittle when exposed to certain chemicals (e.g. chlorinated water).

Steel pipes are manufactured in three classes, namely light, medium and heavy. There are various specifications to which steel pipe is manufactured in South Africa, the SABS specification generally being used nowadays for the sizes and classes for which it is available. SABS specification No 62/1971 is used for steel pipes with nominal diameters of up to 150 mm.

The following aspects must be taken into account during planning of the use of steel pipelines:

- Couplings, e.g. flanges must be compatible.
- Allowance must be made for flexible couplings or for cutting and fitting on site in cases where a minor deviation of dimensions may occur.
- Joints cut and welded on site must be treated against corrosion.
- Anchored flexible couplings must be used in cases where one or more of the pipes are not properly anchored.

3.2 Asbestos and concrete pipes

Asbestos cement (AC) and concrete pipes should also be used subsurface and because there is no flexibility proper installation is very important. The pipe should be laid in a trench with a sand filling to stabilize the bottom of the trench. It can however also be used above ground because it is not affected by the sun. Both asbestos cement as well as PVC pipes have constant outside diameter (COD), which means that the two types can be coupled where necessary.

Figure 1. Concrete pipes being repaired with VJ couplings

Note: *Because of health risks involved in the manufacturing of asbestos products, concrete and fibre glass pipes have replaced the asbestos types.*

Figure 2. PVC and asbestos pipe coupled with cascade clamp

3.3 PVC pipes and fittings

Unplasticized polyvinyl chloride (uPVC) pipes are less ductile than polyethylene pipes but do still offer elasticity to absorb mild deflections and uneven ground conditions.

PVC pipe fittings are connected in two ways, namely the glued PVC fittings or insert (Boseng) type fittings. PVC pipes should be installed subsurface to prevent ultraviolet degradation as well as mechanical damage. Where PVC pipes are used above ground it should be protected by paint or other physical covers.

Advantages

- Corrosion resistance
- Pipes are light and can be easily handled
- Smooth inner walls have very good flow characteristics, that is low friction losses
- Pipes are joined quickly and easily by integrated rubber ring joints, solvent welding and socket fittings
- uPVC is resistant to all chemicals pumped through irrigation lines

Disadvantages

- uPVC becomes brittle at very low temperatures
- The permissible working pressure must be lowered at temperatures above 25°C
- uPVC has a relatively high thermal expansion coefficient compared to steel

Table 6. Troubleshooting for uPVC pipes[7)]

Problems	Possible causes	Solutions
1. Pipe splits	Surge pressure exceeding the pressure class of the pipe	Replace pipe with a higher class Control pressure
	Waterhammer in system	Put in air valves Reduce flow velocity Change the operational sequence of the system
	Poor quality	Replace pipe
	Damaged pipe	Replace or repair damaged pipe
2. Pipe bursts in a herringbone fracture along its entire length	Water hammer in the system, usually induced by the rapid recolution of air in the system	Investigate air entrapment in the system and install air relief valves
3. Pipe flattens causing stress cracking	Negative pressures in the line	Provide air valves to allow air into system Provide a non-return valve
4. Joint leaks – seal pushed into the pipe	No lubrication during jointing	Use gel lubricant
	No camfer on the pipe spigot	Camfer pipe to 15^0
	Seal inserted the wrong way round	Insert seal correctly
5. Joint leaks-seal extruded out of the pipe	Air in the line trying to escape	Purge the line at low pressure during commissioning
	Poor alignment of the joint	Ease the alignment horizontally and /or vertically
6. Joint leaks – constant dripping	Sand/grit behind the joint	Remove and clean properly

Problem	Possible causes	Solution
	Pipe spigot over-inserted into the socket not allowing movement	Ensure pipe is only inserted up to the entry mark
	Poor quality of housing	Cut out joint and repair
	Pipe diameter under size	Replace pipe
7. Solvent cement joint pulls out	Surface not prepared properly	Use sandpaper and a solvent cleaner
	Solvent cement is old and does not bite into the surface	Use new pressure cement that has strong smell and is not too thick
	Pipe too small or socket too big	Replace pipe or socket
	Solvent cement not cured properly	Allow longer curing time, especially at low temperatures
	Too much solvent cement in the joint area, softens the pipe	Only use sufficient to just cover both surfaces
8. Pipe splits near a solvent weld joint	Too much solvent cement I the joint area, softens the pipe	Only use sufficient to just cover both surface
9. Small hole appears in the pipe wall	Foreign particles in the raw material	Repair hole or replace pipe

3. 4 Low and High Density Poly Ethylene (poly) pipe – LDPE & HDPE

- LDPE (Poly) pipe are the most flexible and easy to use pipes generally used in irrigation. It is however also affected and degraded by ultraviolet (UV), and should therefore be used sub surface as far as possible to increase the life span. LDPE pipe has constant inside diameter (CID), and the connectors are inserted into the pipe. This means that a 50 mm pipe is 50 mm measured on the inside.
- HDPE (High density poly ethylene) pipes are stronger and more resistant to sunburn and mechanical damage, but are made of similar plastic compounds and are therefore also affected by ultra violet. HDPE pipe has constant outside diameter (COD) and the connections are used on the outside of the pipe only. A 50 mm HDPE pipe therefore has a smaller inside diameter, and that it will fit into a 50 mm LDPE pipe.

Table 7. Trouble shooting for low density polyethylene pipes [7)]

Problems	Possible causes	Solutions
1. Stress cracking at joints	Insert fitting too big	Use reputable suppliers
	Pipe material is of poor quality	Replace pipe with SABS quality pipe
2. Pipe crumbles like a biscuit	Excessive Ultra Violet exposure	Bury pipeline
	Poor quality of pipe, usually from regrind material	Purchase pipe from reputable manufacturers
3. Pipe bubbles and splits	Under specification wall thickness on one side	Cut out and replace pipe
	Pressure class of pipe is exceeded	Use higher class of pipe or reduce pressure
4. Small hole appears in the wall of the pipe	Foreign particles or unmelted pellet in the side wall	Cut out and repair
5. Joints “pull out”	Not clammed properly	Use hose clamps
	Pipe too big or fitting to small	Replace pipe or fitting
	No allowance for expansion or contraction	Provide expansion loops in long line exposed to the sun

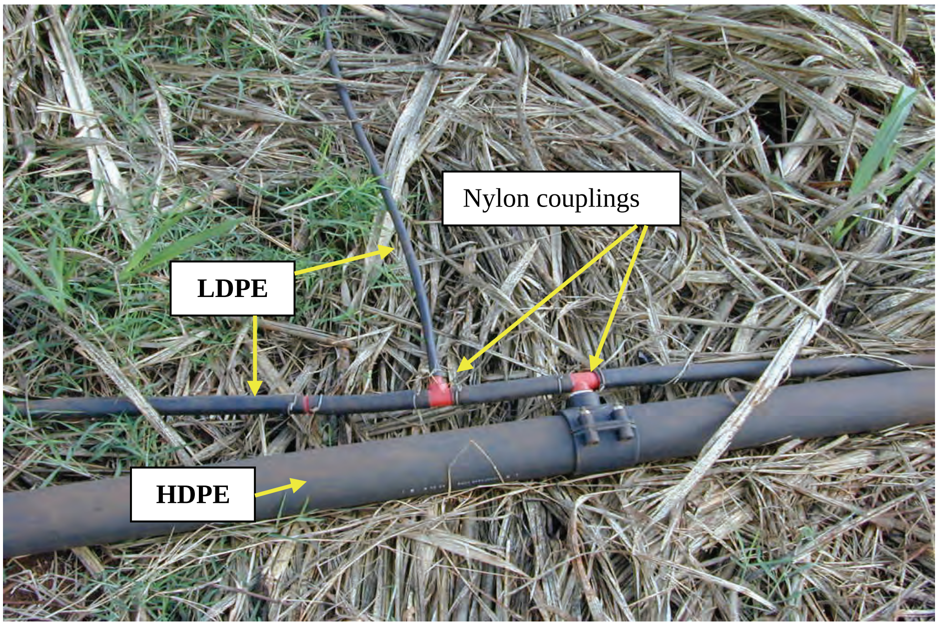


Figure 3. Low and high density Poly Ethylene (poly) pipe

3.5 Quick coupling irrigation pipes and fittings

Quick coupling pipes are for rapid, easy and effective coupling purposes. The advantage is that the pipes can withstand rough treatment but are still light enough for manual labour. Quick coupling pipes are made of steel or aluminium. There are four standard types of quick coupling pipes and each manufacturer has its own characteristic pipe name. The sketches, however, enable the reader to identify the different types and make a choice.

3.5.1 Latch type

These pipes are manufactured from cold rolled sheet metal with couplings welded to both ends; the completed pipes being galvanized in molten zinc. This type of pipe has an easy coupling action with no levers and is also available in aluminium. Standard lengths: 3 m and 6 m

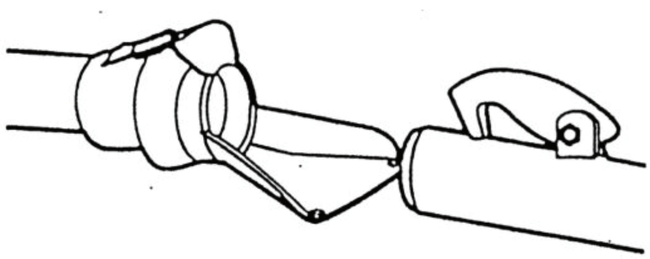


Figure 4. Latch type coupling

3.5.2 Perrot type

These pipes are manufactured from cold rolled sheet metal with couplings welded to both ends; the completed pipes being galvanized in molten zinc. A positive coupling mechanism is used which seals under pressure and suction conditions. Standard length: 6 m

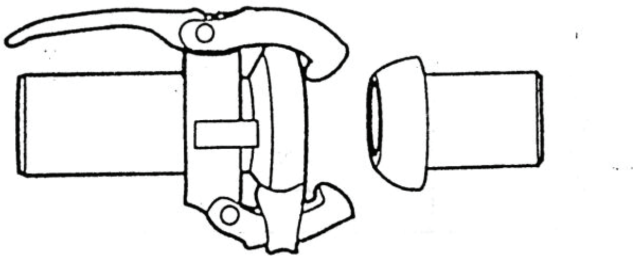


Figure 5. Perrot coupling

3.5.3 Bauer type

These steel pipes are covered with a zinc layer inside and outside. They can withstand rough treatment and the coupling mechanism is the same as for Perrot pipes. Standard length: 3 m or 6 m except the latch type, that is 6 m.

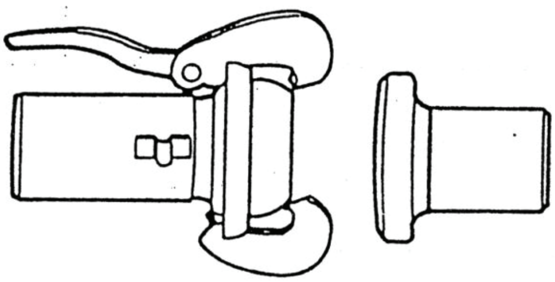


Figure 6. Bauer coupling

3.5.4 Plastic quick coupling pipe

These pipes are similar to aluminium and steel quick coupling pipes and are manufactured from high-density polyethylene (HDPE) with Bauer or latch couplings welded to the ends. Standard length: 6 m

3.6 Flexible suction pipes

Suction pipes for pumps are manufactured from plastic or rubber and are internally reinforced with a steel coil to withstand suction and pressure forces. Steel and quick coupling pipes with positive couplings may also be used as suction pipes.

Note: *With all pipe types the correct application as well as correct installation is the best way to ensure extended use of the equipment.*

4. Valves

Valves are also specialized equipment and need to be maintained. Hydraulic valves utilize small diameter pipes for operation, which need to be cleaned to prevent blockages.

4.1 Hydraulic Valves

These valves operate with water pressure opening a rubber diaphragm. This diaphragm is controlled on the top by a spring on the top. With time and operation the spring may break, and pierce through the rubber. This causes failure to close, and also to control pressure. The valve needs to be opened and cleaned and the damaged parts replaced.

Figure 7. Bottom half of hydraulic valve

Figure 8. Damaged rubber diaphragm

4.2 Gate, butterfly and ball valves.

These valves operate with a physical barrier which closes the flow opening in the valve. Spindles, shafts and balls need to be greased with water resistant grease or compound. When opening large valves with big shafts one should turn the wheel to open the valve and when the fully open position is reached, turn the wheel half a turn back to prevent it locking and getting stuck.

4.3 Air Valves

Air valves should be opened and checked for dirt and obstacles which makes the air valve leak water. The float inside the valve usually has a rubber connection which sometimes breaks off and needs to be replaced. Insects also tend to enter the air valve outlet, causing it not to seal tightly.

Figure 9. Opening a 25 mm plastic air valve to clean

Tables 8 to 11 show troubleshooting tables for different valves.

Table 8. Troubleshooting for pressure relief/pressure sustaining valves[8)]

Problem	Possible causes	Solution
1. Valve does not open	Pilot valve spring is set to tight	Turn adjusting nut to (-) minus till valve opens
	No pressure in system	Switch on pump/Open shut off valve
	Hand control set incorrectly	Make sure of setting
	Worn pilot valve	Replace/repair pilot valve
2. Valve does not close	Control filter blocked	Clean pilot valve
	Internal ports in pilot valve blocked	Make sure of setting
	Dirt in main valve	Remove valve or moving parts and check for damage
	Diaphragm faulty	Test for damage: • *Single chamber:* open plug on top of diaphragm chamber. Disconnect all pipes to diaphragm chamber. If waterflows out constantly, replace diaphragm. • *Double chamber:* if water flow out from bottom chamber constantly, with pilot valve connected, but stops as soon as pilot valve is disconnected, replace diaphragm.

Table 9. Troubleshooting for pressure reducing valves [8)]

Problem	Possible causes	Solution
1. Valve does not open	No pressure in system	Switch on pump/Open shut off valve
	No flow in system	Switch on pump/Open shut off valve
	Pilot valve set incorrectly	Turn adjusting nut to (+) plus
	Hand control set incorrectly	Check
	Pilot valve blocked	Remove and clean
2. Valve does not close	Control filter blocked	Remove and clean
	Hand control set incorrectly	Check
	Dirt in main valve	Remove valve or working parts and check for damage
	Diaphragm faulty	Test for damage: • *Single chamber:* open plug on top of diaphragm chamber. Disconnect all pipes to diaphragm chamber. If waterflows out constantly, replace diaphragm. • *Double chamber:* if water flow out constantly with pilot valve disconnected, replace diaphragm. • *Take care:* This test will cause the valve to go to fully open position. Ensure that no damage will be done to the system.
3. Valve does not control pressure	Pilot valve is worn	Check/replace/repair
	Valve constantly opens and closes	Control valve too large /Pressure difference too big/Flow too low: replace control valve, delay operating speed or use another types of pilot valve
	Air trapped in control chamber	Loose seal at highest point of control chamber and let air escape

Table 10. Troubleshooting for electrical control valves[8)]

Problem	Possible causes	Solution
1. Valve does not open	No electricity supply	Turn adjusting nut to (-) minus till valve opens
	No pressure in system	Switch on pump/Open isolator valve
	Solenoid: i) Shaft is stuck ii) Ports blocked iii) No activation click or coil is damaged	i) Check and clean ii) Check and clean iii) Replace spool: ensure that supply current is the same as solenoid specifications
	Hand control set incorrectly	Check
2. Valve does not close	Control filter blocked	Remove and clean
	Hand control set incorrectly	Check
	Solenoid: i) Remains switched on ii) Ports blocked	i) Switch power off ii) Check and clean
	Dirt in main valve	Remove valve or working parts and check for damage
	Diaphragm faulty	Test for damage: • *Single chamber:* open plug on top of diaphragm chamber. Disconnect all pipes to diaphragm chamber. If waterflows out constantly, replace diaphragm. • *Double chamber:* if water flow out of bottom chamber constantly with pilot valve disconnected, but stops as soon a pilot valve is disconnected, replace diaphragm.

Table 11. Troubleshooting for sluice valves [8)]

Problem	Possible causes	Solution
1. Valve leaks	Packing gland faulty/loose	Tighten packing glands, replace packing
2. Valve does not function	Screw thread damaged	Replace nut and/or shaft
	Bush on sluice broken	Replace bush
	Sluice has corroded and rusted	Dismantle and clean
	Valve has difficulty functioning-turns heavily.	Relieve tension on packing gland, lubricate screw thread.

5. Filters

In irrigation systems where filtration or other forms of water treatment is required, a well designed and correctly filtration unit is very important for an efficient operating irrigation system. Ring and mesh filter openings must be smaller than 1/5th of the emitter orifice diameter. The appropriate micro emitter manufacturers' recommendation must be followed. The following norms are recommended by the ARC IAE [8]:

- recommended pressure drop over a clean ring filter : ≤ 10 kPa
- recommended pressure drop over clean filter bank: ≤ 30 kPa
- maximum allowable pressure drop over a filter bank before backwashing ≤ 70 kPa

When using a sand filter, the following norms apply:

- maximum allowable flow rate through a clean sand filter: flow rate ≤ 50 m^3/h per $m^{3,}$ with a maximum drop of ≤ 10 kPa
- minimum backwash rate must not exceed 1.2 time the filtration rate. The backwash time of sand filters can vary between 90-180 seconds.

5.1 Cleaning of filters

Filters are generally cleaned by back flushing – the action of reversing the flow of water through one filter to flush out accumulated dirt from another. From time to time the filters need to be manually opened and checked for proper cleaning because depending on the nature of dirt, the effectiveness of back flushing may not be good enough to thoroughly clean the filter.

- Measuring pressure before and after the filter can give a good indication of how clean the filter is. One should however know what the pressure drop over a clean filter is to be able to evaluate the specific type of filter.
- In disc filters the discs can be removed and dipped in peroxide for a few hours to remove iron and manganese deposits and bacteria.
- Acid can be used where carbonate and salt deposits are apparent.
- In sand filters the filter needs to be opened and the sand checked by digging out a handful of sand after back flushing to evaluate it for dirt.
- Sand can be removed and rinsed manually, but good practice is to replace the sand to ensure proper operation.
- Screen filters need to be checked and also need chemical cleaning depending of the nature of the dirt. Screen filters are not to be rubbed or scrubbed, but rather cleaned by high pressure water or chemicals.

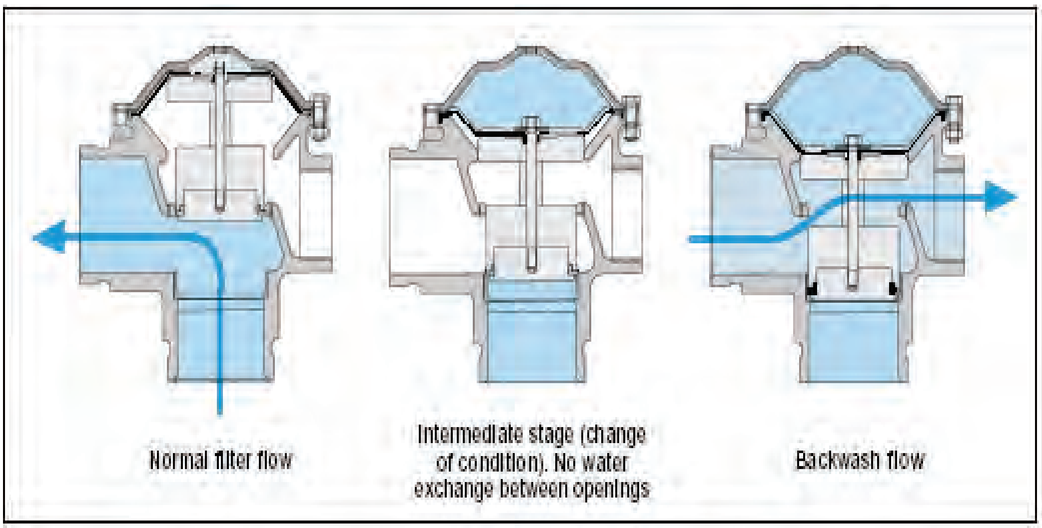


Figure 10. Filter flush valves – operation

5.2 Filter cleaning techniques

Clean filtered water will loosen the dirt that is retained between the discs, so that it is removed through the back-flush outlet. A valve system controls this action.

The following techniques can be applied:

1) **Manual cleaning**. With smaller systems, using single filter element irrigation must be stopped temporarily by closing the valve. The element must then be removed by loosening the discs and cleaning them by hand. Screen filters can also be sprayed clean with high pressure. With sand filters the sand can be removed and rinsed, or simply replaced.

Figure 11. Spraying filter rings with high pressure water

2) **Back Flushing**. Where two or more filters are used and pressure is sufficient, changing the flow direction of the water cause a back-flush action. In this case the water flows backwards through the filter (back-flush) by closing the inlet valve and opening the backwash outlet valve (Figure 10). Water goes through filter A and enters filter B from the outlet side to create the reverse flow or back-flush. All types of filters can be back flushed in this way.

Filter-banks are constructed of two or more elements so that only water that was already filtered is used to clean the elements without interruption of irrigation. The more filter units there are, the less the pressure of the system will be affected by the back-flush action.

With the Arkal Spin-Klin® filter a technique is applied where an element with jets is located inside the filter discs. With flushing the disc spring is relieved and the jets actively spray the disc clean from the inside. This is the most efficient flushing method as it is an active flush of water with the spray jets.

a.) Back-flushing of smaller systems can be done **manually** by closing inlet valves and opening flush valves by hand.
b.) Back-flushing is usually done **automatically** by means of a flush timer (**time flushing**). Flush duration as well as time between flushing events can be set, for example to flush every 2 hours for 40 seconds.
c.) Flushing can also be done with a pressure switch that measures the **pressure difference** (△P) up-stream and down-stream from the filter. When the pre-set value is reached, flushing starts automatically.

3) **Chemical cleaning**. Where dirt is of organic nature, and where manganese and iron levels in the water is high, back-flushing and even manual cleaning is not always effective. In these cases dirt has to be removed chemically using hydrogen peroxide, chloride and even acid, depending on the type of dirt. Filter elements can either be removed or soaked in the chemicals, or it can be injected into the system, cleaning the filters as well as the rest of the system.

Figure 12. Clogged filter rings

Figure 13. Rings in peroxide

Table 12. Trouble shooting table for disc and mesh filters[8)]

Problem	Possible causes	Solutions
Proof filtering	Wrong filtering fineness of disc/mesh.	Replace discs/mesh.
	Too few discs.	Add discs.
	Too high pressure difference over filter.	Adjust back-flushing cycle or time
	Holes in mesh.	Replace mesh.
	O-ring damage.	Replace O-ring.
Continuous high pressure drop over filters	Wrong choice of filters.	Replace filters.
	Insufficient back-flushing time.	Adjust back-flushing time.
Back-flushing valves leak	Dirt in valve seat.	Clean.
	Diaphragm of valve leaks.	Replace.
	O-ring on shaft damaged.	Replace and lubricate.
Increasing frequency of back-flushing action	Back-flushing flow or duration is not long enough to clean filter.	Adjust back flushing flow.
	Diminished water quality at source.	Create additional filter capacity or reduce flow or pre-filter.
	Back-flushing action of filters insufficient.	Clean by hand.
Automatic back-flushing does not take place	Electricity off in control-box, fuse melted, contact breaker tripped.	Switch on, check fuse and repair.
	Wrong setting of pressure difference switch.	Adjust setting.
	Solenoids faulty.	Test, clean, replace if necessary.
	System pressure insufficient to activate valves.	Check system, especially inlet sieve.

5.3 Management of a filter system

The most important aspect of maintenance on the filter system of an irrigation system is to clean it regularly.

5.3.1 The pressure loss and period between back-wash actions

When the pressure loss becomes too high as a result of clogging then:

1) mesh filters can be torn and give way;
2) dirt is pressed so tightly in-between the rings (discs) that it is not released during back-flush; and

3) dirt that is forced into sand-filters form lumps which will eventually limit the flow area.

The pressure loss must be measured regularly. When it is abnormal, the following actions must be taken:

1) When the pressure loss of a filter becomes too high (>50 kPa) it can mean that the dirtiness has increased and that the period between back-flush actions must then become shorter. The back-flush cycle can be lengthened as soon as the water becomes cleaner, so that less water is wasted. [Pressure loss should be measured according to specifications of the specific type of filter].
2) Whenever the drop in pressure across a ring filter becomes too high immediately after a back-flush action, it can mean that:
   a] dirt is pressed so tightly in-between the rinse (discs) that it cannot be flushed out and therefore the rings must be cleaned by hand; or
   b] the rings are so clogged that the smaller flow area becomes so small and friction loss so high that the clogging has to be removed by using acid.
3) Whenever pressure loss across a sand filter becomes so high after a back-flush action, it can mean that the friction loss has increased as a result of clods formed in the sand-bed that is not flushed out.
4) Whenever the pressure loss across a mesh filter after a sand filter increases, it must be washed and if it occurs often, it means that too much dirt has passed through the sand filter and the sand must then be replaced. The filtering ability of the sand decreases as the particles become rounder and smoother.

5.3.2 The time duration and flow-rate of a back-flush action

To save water, the back-flush action must be as short as possible but long enough to remove the dirt (until the flush water is clean). With sand filters, a longer flushing time is usually needed than with disc and screen filters. However the frequency of flushing is usually longer (less frequently) because of a much larger filtration surface.

The higher the flow-rate when back-flushing ring filters or flushing mesh filters, the better it is done, but with sand filters it is important to maintain the back-flush flow rate of approximately 60 m^3/h for each square meter (m^2) of sand-bed area. A too low flow rate will not loosen the dirt, while a too high flow-rate will disturb the sand-bed and sand will be flushed out. The flow rate of back flush is a function of design, and should be done according to norms for filter design.

Essentially the duration of the back flush action should be tested in field according to the prescribed allowable pressure differences.

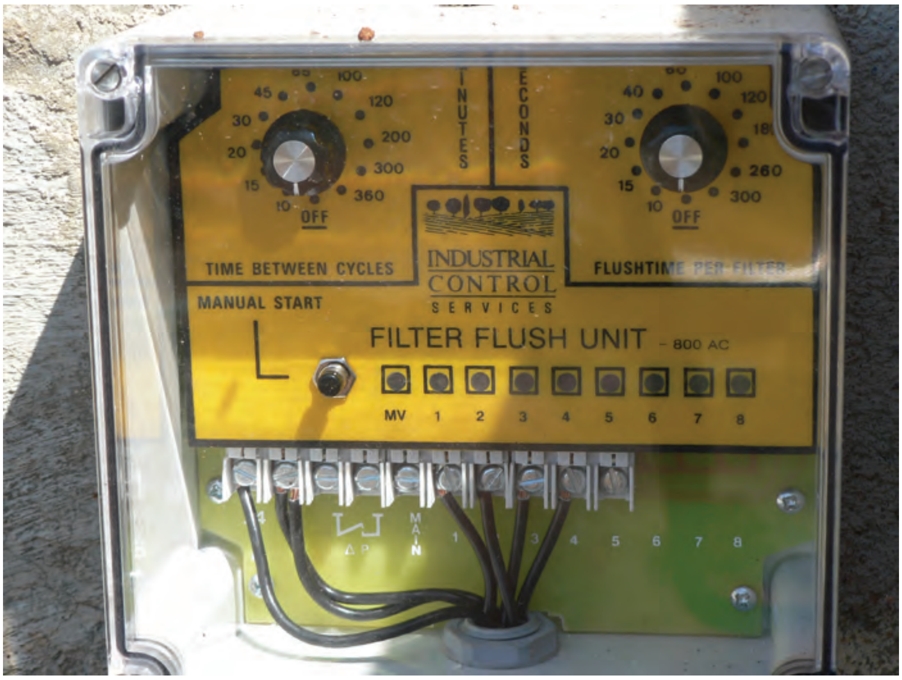
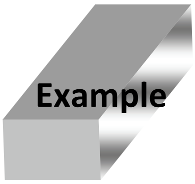


Figure 14. Filter flush timer

All flushing timers work on two settings, namely:

- Time between cycles, which is the time (minutes) from one flushing event to the next event
- Flushing time per filter is the active flushing of each filter (usually in seconds.



If the left hand button is set on 120 and the right hand on 40, it means that the filter will flush every 120 minutes (3 hrs) for the duration of 40 seconds.

- A third factor can be added, which is pressure difference, or △P (Delta P = pressure difference). This works with a pressure switch which is connected to the filter upstream and downstream side. This serves as a backup to ensure that the filter flushes on a set pressure difference and not only after the set time.

Table 13. Trouble shooting table for sand filters[8)]

Problem	Possible causes	Solutions
Poor filtering	Too high a flow through the filters – causes that sand flushes out or forces dirt through filters to outlet.	Reduce flow through filter or create additional filter capacity.
	Wrong sand in filters.	Replace sand.
	Too high a pressure difference forces dirt through filters and outlets.	Adjust back-flushing time.
	Insufficient sand depth lets dirt through.	Supplement sand.
Continues high pressure drop over filters	Sand has formed a layer by sedimentation or blockages.	Remove affected layer of sand and replace with clean sand.
	Insufficient back-flushing flow.	Adjust back-flushing valve.
	Too little sand causes poor back-flashing.	Supplement sand.
	Wrong choice of filters.	Replace filters.
Sand appears downstream in system	Sand is too fine.	Replace with correct type of sand.
	Mechanical damage to rings/rosettes.	Repair or replace.
Back-flushing valves leak	Dirt in valve seat.	Clean.
	Diaphragm of valve leaks	Replace.
	"O-rings" on shaft damaged.	Replace and lubricate.
Increasing frequency of back-flushing action	Back-flushing flow or duration is not long enough to clean filter.	Adjust back-flushing flow.
	Insufficient sand depth.	Supplement.
	Diminish water quality at source.	Create additional filter capacity or reduce flow or pre-filter.
	Tunnel forming.	Loosen sand manually or use air for back-flushing.
Automatic back-flushing does not take place	Electrical supply to control-box is off, fuse melts, contact breaker tripped out.	Switch on, check fuse and repair.
	Faulty adjustment of pressure difference switch.	Adjust.
	Solenoids faulty.	Test, clean, replace if necessary.
	System pressure insufficient to activate valves.	Check system, especially inlet sieve.
Sand filter blocked	Flow rate through filters too high.	Reduce flow or enlarge filter bank.
	Poor chemical treatment.	Treat with chlorine/acid.
	Wrong setting of the back-flushing valves.	Adjust back-flushing time and cycle.
	Wrong choice of filters.	Replace filters.

6. Water meters

Water meters need to be serviced and calibrated from time to time. The impeller type meter can accumulate dirt and turn slower and slower. It is usually best to replace the meter.

Where malfunction is suspected the counter propeller can be removed by first closing the water supply and then loosening the bolts to remove the gauge unit. If no visible problem like some algae or plant material sticking to the propeller, the unit should be sent to the agents for service or it should be replaced.

Figure 15. Propeller type water meter

Activity

Small group activity

1 You walk into a pump house and there is a loud noise. You feel the pump casing and it is really hot. What can be the possible causes and what steps can you recommend correcting the problem?

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2 A farmer complains that his overhead sprinklers do not reach the distance it should and that it leaves dry patches. It seems the pressure is too low, but the pump is still new. Which aspects can you look at to find solutions for the problem?

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3 What is the first step when operating a pump for the first time?

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4 What advantages exist in the practice of starting a centrifugal pump at closed valve?

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5 A disc filter system is back-flushed automatically with a flush timer. According to the reading on the pressure gauge however, there is still a large pressure drop in the filters after back-flushing. This indicates dirty filters. What steps can be taken to ensure that filters are flushed efficiently?

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My notes...........

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Authenticator: Dr P Reid

Module 2

Maintenance of irrigation systems

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- Maintenance of sprinkler irrigation system
- Maintenance of centre pivot
- Maintenance of micro irrigation system
- Maintenance of drip irrigation system
- Line flushing
- Chemicals that can be used for cleaning of dripper lines

Table of contents

The maintenance of an irrigation system is very important and this module aims to present the major aspects to take into consideration with the management and maintenance of the emitters of an irrigation system as effectively as possible. A lack of maintenance of an irrigation system usually results in a decreased performance like the occurring of blockage in the irrigation system which results in a lower uniformity; reduced flow rates and higher friction losses.

An effective maintenance program for irrigation systems includes the following:

- Servicing schedules (which includes an inventory and spares that are kept in stock)
- Replacement schedules for the different irrigation system components

A complete set of guideline on maintenance of in-field irrigation systems are found in the ARC IAEs Irrigation User Manual and from the various manufacturers of irrigation products.

The following aspects of static and moveable irrigation systems can be applied for troubleshooting as illustrated in Table 1.

Table 1. Troubleshooting guidelines for static and movable systems[8)]

Problem	Possible causes	Solutions
Emitter pressure incorrect	Distribution system incorrectly designed.	Do complete evaluation of distribution system.
	System not installed according to plan, or additions have been made.	Compare existing layout to layout on plan, enquire whether producer has added on or increased emitters and look for signs thereof in field.
	Emitter opening worn or incorrect nozzle size installed.	Do evaluation.
	Wear on pump.	Replace impeller.
	Leakages.	Repair leaks.
	Too many emitters.	Change system set-up.
Low discharge of emitters of micro systems	Clogging as result of water quality.	Inject acid/chlorine depending on problem.
Pump pressure incorrect	Leaks in supply systems.	Repair leaks.
Emitters discharge incorrect	Wrong nozzle sizes.	Replace emitters.
	Emitter pressure incorrect.	See causes/solutions above.

1. Sprinkler irrigation systems

Sprinkler irrigation is adaptable to most crops, soils and topographical circumstances. However for an effective system even water distribution over the total land surface and careful judgement of the design criteria is required. With careful selection of nozzle sizes, riser heights, operating pressure and sprinkler spacing, water can be applied uniformly at a rate lower than the infiltration rate of the soil, thereby preventing runoff.

The following guidelines are recommended regarding the operation and maintenance of the quick coupling system:

- **Select and use of the correct stand pipes**

The length of pipe needed to remove turbulence varies with sprinkler discharge. The sprinkler should be placed at least 0, 6 m above the crop. Standpipes are normally available in the following lengths: 0,2 m; 0,5 m; 1,0 m; 1,2 m; 1,5 m; 2 m and 3 m (they can also be customised) with diameters ranging from 20 to 25 mm.

- **Choose the correct type of sprinkler for the specific irrigation requirements**

Many sprinklers on the market are sold together with technical documentation. When choosing a sprinkler the following must be taken into account:

- Uniformity of water application.
- Precipitation rate: Function of discharge, wetted diameter and sprinkler spacing.
- Drop size distribution: Function of nozzle diameter, pressure and pressure variation.
- The cost.
- Back-up service

The impact-drive rotating sprinkler is the most popular. The impact drive has a weighted spring-loaded drive arm to provide the force to rotate the nozzle assembly. The sprinkling stream deflects the arm sideways and the spring pulls the arm back to the nozzle assembly and into the path of the stream. As the drive arm completes each swing cycle it impacts against the nozzle assembly rotating it slightly. The advantage of the rotating sprinkler is its ability to apply water at a slower rate while using relatively large nozzle openings.

- **Operate the system at the designed pressure**

a. The system must be irrigated at the design pressure else there will be an uneven distribution of water. A too low sprinkler pressure does not break up the water jet thoroughly and the so-called doughnut effect with a poor distribution is obtained. With a too high pressure the water jet is broken up too fine with a mist effect that can cause great losses. It was found in practice that the optimal operating pressure (kPa) of the sprinkler is between 60 and 70 times the nozzle diameter (mm). This is applicable to nozzles of 3 to 7 mm diameter. A 4 mm nozzle therefore works best at a pressure of between 240 and 280 kPa. (2.4-2.8 Bar)
b. When the wind speed reaches more than 16 km/h, the application efficiency of the system reduces drastically and it is better to stop irrigating. Water that sprays too high into the air is more affected by wind. A nozzle that sprays 32° from the horizontal obtains the maximum sprinkler distance.
c. Night irrigation is much more effective than daytime irrigation because of low evaporation loss. If suitable to the soil and the crop, it is best to have set-ups of 11 hours with 1 hour moving time, i.e. sprinklers are only moved mornings and evenings.
d. The water distribution on the field should be tested once a year by setting up rain meters according to the procedure prescribed in the *Irrigation Evaluation Manual of*

e. *the ARC-Institute for Agricultural Engineering*[8)]. System capacity and pressure must also be determined once a year.

- ## Maintenance of sprinkler irrigation system

With an increase in the age of irrigation systems, the overall pressure decreases and the flow rate increases as the nozzle wear, and variation in both increases with impact sprinklers the nozzle, spring and shaft needs inspection and also replacement. Nozzles wear due to impurities in the water and get bigger and bigger.

When a 4 mm nozzle wears out to 5.5 mm, the water delivery doubles and the result is that the system pressure drops due to the increased pumping volume. The spring also wears after a number of years and this negatively impacts on the distribution pattern. The shaft can be greased regularly to prevent rust and enable easy operation.

Wearing of sprinkler nozzles is measured with a specially machined apparatus (Figure 1). The measurement indicates the amount of wear (mm) on the sprinkler nozzle. If the wear is more than 5%, the nozzles must be replaced. An increase of 5% in nozzle area means a 10% increase in delivery and power demand that means additional operating cost and possible over-irrigating. Regular measurements can be done when the system is in operation or when switched off.

Figure 1. Measuring of sprinkler nozzle size (Source F Reinders)

If a nozzle without a flow guide (little fins inside) gets blocked, it can be carefully cleaned with a piece of wire. However, a sprinkler nozzle that has a flow guide must be cleaned carefully (not with wire) to prevent damage inside. The following maintenance schedule is recommended:

Table 2. Maintenance schedule for sprinkler irrigation systems (manual control)

Monitor	With each cycle	Annually
Inspect the system for leakages & blockages	X	
Check system pressure	X	
Check flow rate from nozzles		X
Service air valves and hydrants		X
Check sprinklers for wear and replace springs, washers and nozzles where necessary		X
Flush mainlines		X
Replace rubbers at quick coupling pipes where necessary		X

* *The suggested maintenance schedule can be adapted for automatic permanent systems, e.g. system pressure can be monitored monthly.*

After the irrigation season, before the pipes are stored, the following practices are recommended:

- Mark all the holes in quick coupling pipes with paint so that they can be repaired.
- Remove all gaskets from pipes if they are stored in the sun. Replace all damaged and hardened gaskets.
- Replace all worn male and female pipe fittings.
- Replace all dragline pipes that have more than three joints.
- Check standing pipes for corrosion and replace if necessary.
- Ensure that all standing pipes are the same length and straight.

Figure 2. Hydromatic and piplet

Figure 3. Sprinkler with leaking pressure regulator

Maintenance on dragline systems includes the maintenance of sprinklers as well as checking pipes for leakages. Spacing of sprinklers as well as length of draglines should also be correct according to the design. Piplet and hydromatic connections also need to be firm, and rubbers need to be replaced where leakages occur.

2. Maintenance of moving irrigation systems (centre pivot)

With centre pivots as well as other mechanized systems there are a number of points to be checked regularly. These include the following:

a. **Tyre pressure** should be according to supplier specification and should be correct according to the soil type (1.5-2 bar)

b. **Gearbox** oil should be checked for correct level and oil seals be replaced if there are any leakages.

c. Ensure that **drive shafts** and **protective shields** are clean and free from grass or plant material to prevent damage to oil seals.

d. **Grease** pivoting and moving parts where applicable

e. Check **rubber boots (couplings)** on main pipes for leakages or moving out of position. Also check flanges for leaks – require special gaskets.

f. **Sprinklers** and especially big gun sprinkler check for proper working and leaks or clogging, as well as correct rotation. Sprinkler delivery should be evaluated by putting out rain gauges or cans, and replaced if distribution is not uniform. Older sprinkler types should also be replaced with the more efficient types available. Sprinkler drop pipes can also be lowered to decrease evaporation.

g. Check **drain plugs** for proper operation so that water drains from the system after shut down. This may prevent excessive rust especially where fertigation is done through the system. Rubber seal needs to be turned around to prevent it from bending and sealing permanently.

h. Ensure **roads** are **firm and clear** to prevent grass or leaves winding up on drive shafts and to prevent tyres making deep tracks in wet soil.

i. Open flush valve (**sand trap**) at end of pivot overhang to drain out dirt.

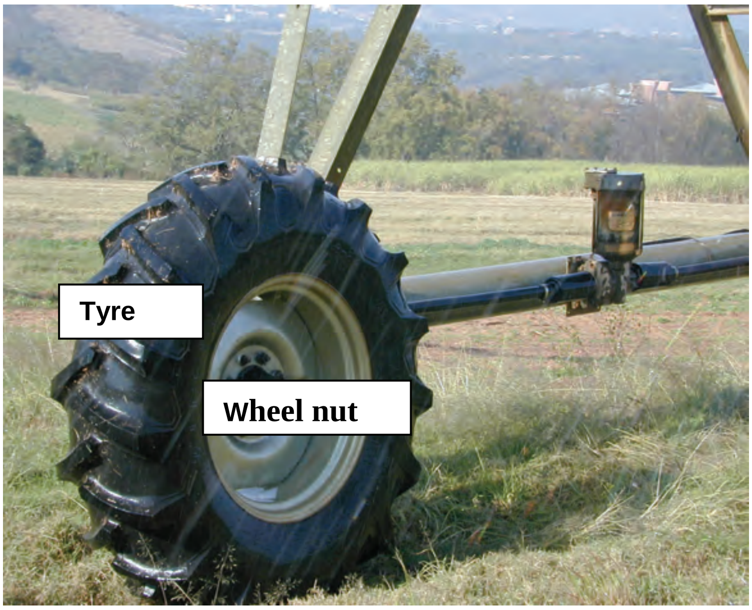
j. **Control insects** nesting in electricity boxes and switches.

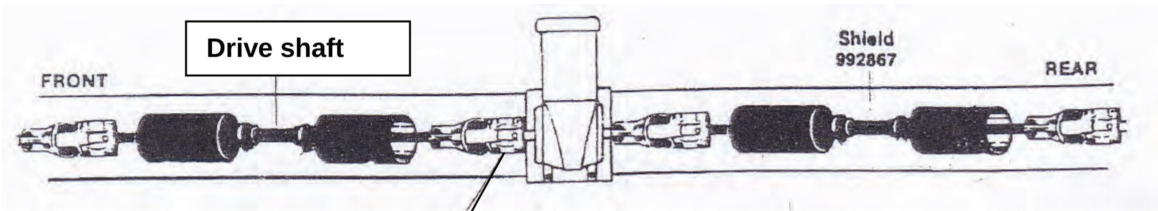
k. **Wheel nuts** should be checked every season

l. **Nuts and bolts** should be tightened to ensure the frame is in tact.

m. Ensure that no **electric wires** are exposed, and electric control panel is kept locked.

n. Check that **indicator light** works when the system is operating.





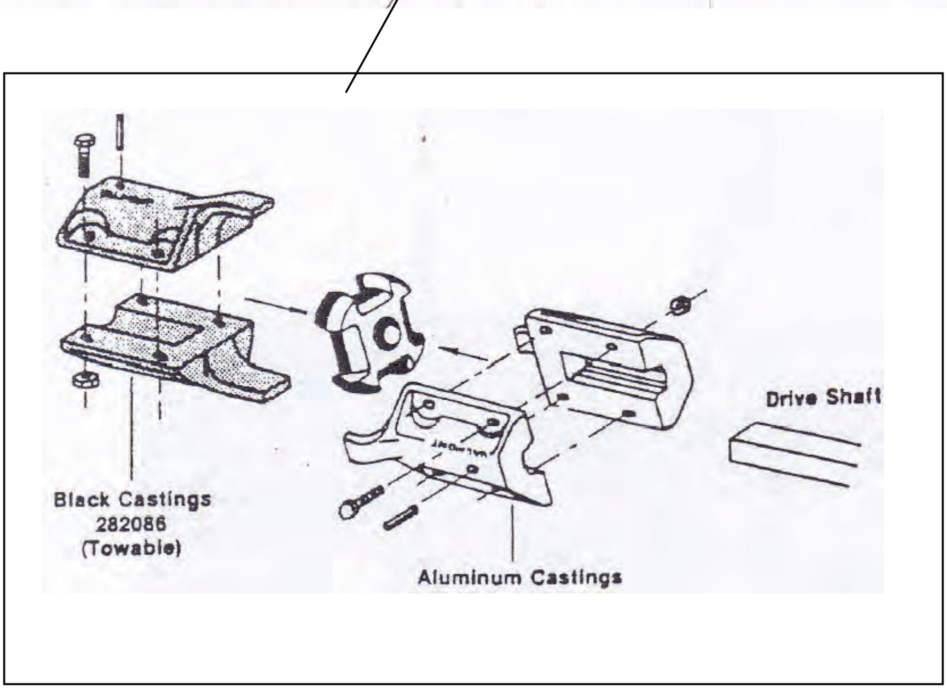


Figure 4a. Schematic drawings of pivot maintenance

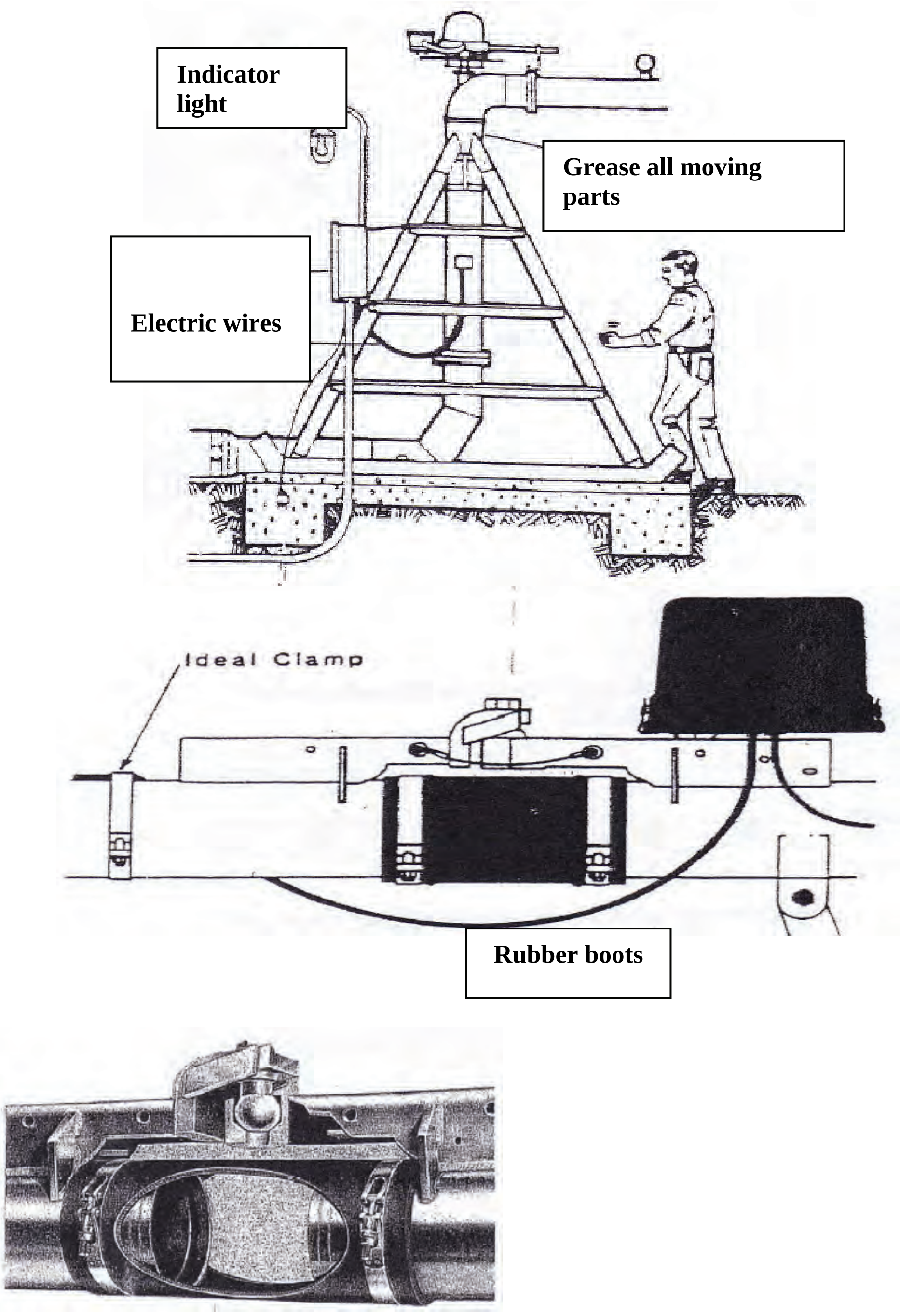


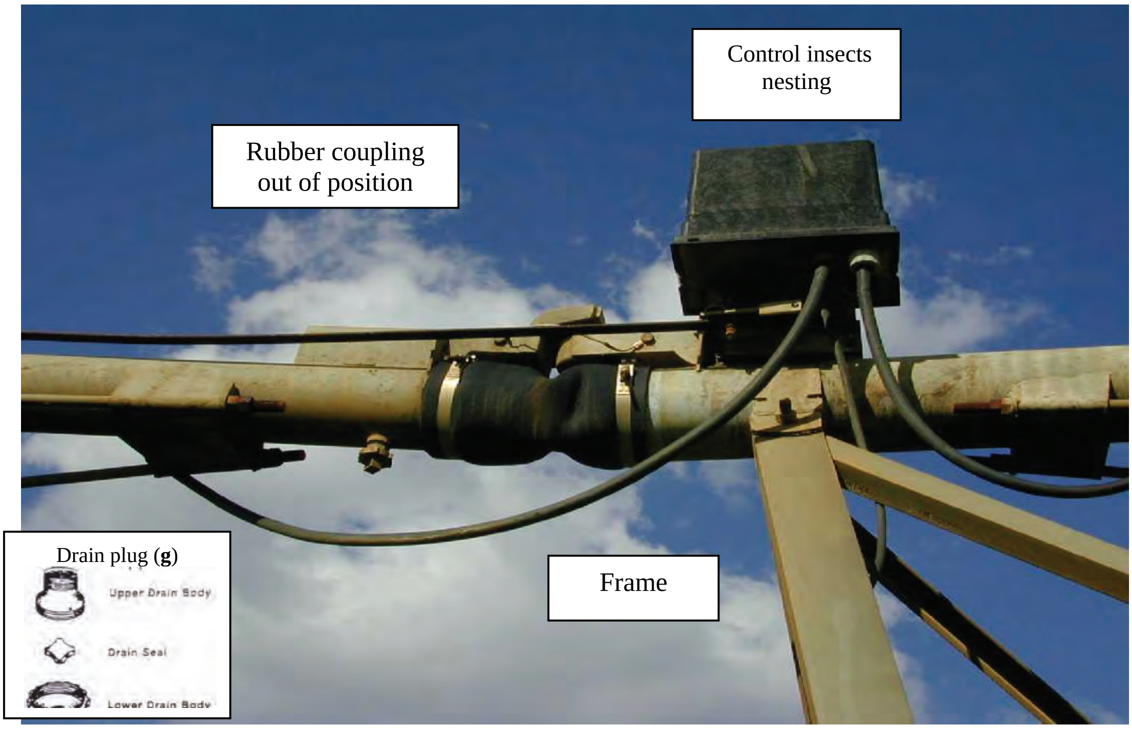
Figure 4b. Schematic drawings of pivot maintenance

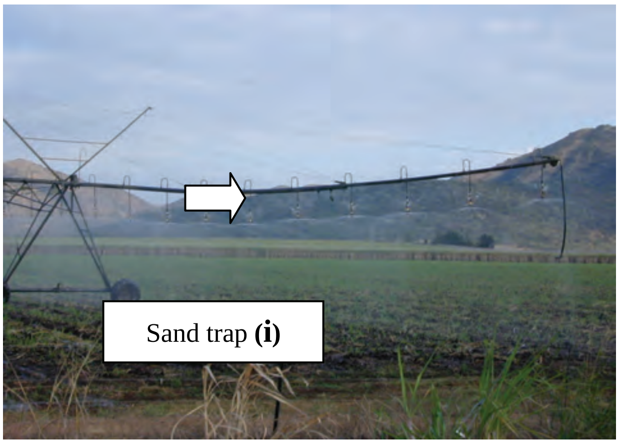
Table 3 illustrates the intervals for maintenance actions appropriate to moving irrigation systems like the centre pivot.

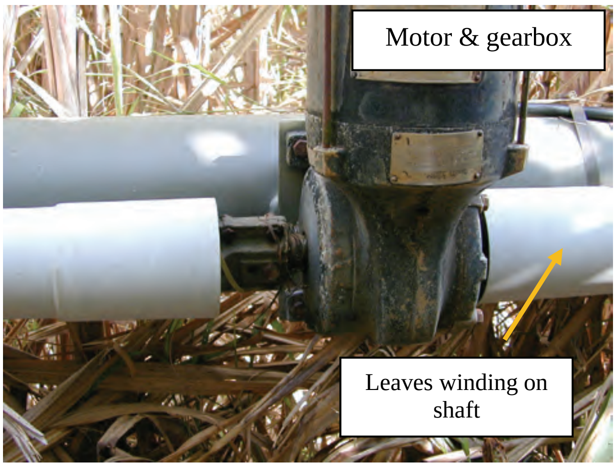
Table 3. Maintenance schedule of centre pivots [8)]

Action	After each revolution	After the 4th revolution	Seasonal
1. Electrical			
Switch on pivot and listen to each motor and starter. If any abnormal sound is heard, remove and service.			•
Replace end tower's electric bulb (if out) and remove dust, insects and water where necessary			•
Check tower panel and main control cabinet. Clean panels, remove dust, insects like wasps,etc.			•
Inspect condition of wiring of pivot			•
Inspect electrical motor cable condition, earth conductor and connections.			•
2. Structure			
Tighten all bolts and nuts where necessary. Ensure that earth conductors are clean.			•
Grease pivot		•	•
Grease pin that holds swing mechanism of towable pivots to prevent rusting		•	•
Check system for leakages. Repair if necessary.			•
Replace gearbox oil			•
Drain and replace lubricants in motors			•
Grease mowing parts and roller bearings	•		•
Check U couplings, grease if necessary			•
Check wheel bolts and adjust a prescribed	•	•	•
Check wheel pressure and adjust as prescribed	•		•
Check flange fittings for leakages, secure and replace if necessary	•		•
Inspect framework for sturdiness – tighten bolts where required	•		•
Check that all the safety switches work			•

Action	After each revolution	After the 4th revolution	Seasonal
Check that all the drainage valves work	•		•
Clean sand trap if necessary	•		•
3. Sprinkler			
Check nozzles for wear, replace if necessary			•
Check that pressure meter works correctly			•
Check the condition of the sprinkler			•
Check pivot pressure and pressure at the beginning of the towers			•
Check for blockages in nozzles	•	•	•
Flush the system			•
4. Equipment			
Check functioning of the end nozzles and check nozzle wear			•
Inspect cut off action of end nozzle – repair or replace if necessary			•
Check stop in slot micro switch, adjust if necessary	•		•
Test the automatic reverse action movement of pivots by switching the hand lever forward and backwards			•
Fill wheel tracks deeper than 150 mm with timber or stones			•


Control insects nesting
Rubber coupling out of position
Drain plug (g)
Upper Drain Body
Drain Seal
Lower Drain Body
Frame


Sand trap (i)


Motor & gearbox
Leaves winding on shaft

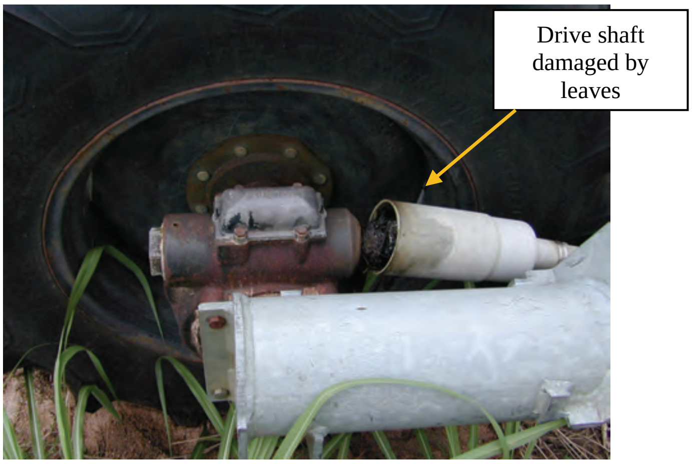


Figure 5 (a-d). Centre pivot with different components

Other important management aspects on centre pivots:

- Install flow meter to monitor any increase in flow due to worn out nozzles.
- Replace complete sprinkler package when necessary.
- Establish whether any alterations had been done on the irrigation system since installation of the pivot.
- If possible replace original sprinklers with more efficient types.
- Monitor whether wheels are constantly running on the same tracks.

3. Maintenance of drip systems

Maintenance of drip systems comprises a program of regular physical action as well as regular chemical treatment. Preventive measures are key aspects in good management of drip systems and include proper filtration as well as regular flushing of the drip system. The type of the treatment will depend on the water quality and nature of dirt in the water.

- Algae and bacteria are treated by the use of chlorine or peroxide.
- Carbonates need to be dissolved by acid treatment.
- Silt and clay particles are flushed out.
- Root intrusion is stopped chemically with specific herbicides.

The use of a flow meter gives a good indication whether all the drippers to a certain block are working. For example the flow to an irrigation block with 10 000 drippers with delivery of 1.6 L/h should theoretically be 16 000 L/h, which translates to 266 litres per minute. It is however sometimes impractical to install a flow meter to each block and could be very expensive.

3.1 Line flushing

Silt and clay particles are carried in river water because of its extremely small size, and are therefore able to go through most filters. These particles assemble in the pipe to form larger size particles which can eventually block drippers. This can be prevented by regular flushing of the drip lines.

Figure 6. Flushing of drip line till water is clear

Flushing comprises opening the end of the dripper line for a few (15-20) seconds to rinse out the accumulated dirt. This should be done in addition to peroxide, chlorine and acid treatments. The poorer the quality of water supply, the more regular flushing is required. In some drip systems all the drip lines are connected to a single pipe with a flush valve at the end. In both cases the design is critical for the system to be able to attain a high enough flow velocity for effective flushing.

Table 4. Recommended flushing intervals

Water quality	Flushing interval
Good	Monthly
Average	Bi-weekly
Poor	Weekly
Very poor	2x per week

3.2 Filtration

Preventive measures include the use of correct filtration as well as regular filter cleaning. Never jeopardize an expensive irrigation system by installing a cheap or inappropriate filter.

Filters – like drip lines – should be cleaned both manually by flushing or hand cleaning, as well as chemically using peroxide, chlorine or acid depending on the nature of the dirt.

See Module 1 of this Part for more comprehensive management aspects on filters.

3.3 Chemical cleaning

- **Carbonates & salts**

Water containing large amounts of calcium carbonate (hard water) or more than 1 mg/L of iron should be acidified to a pH of between 5 and 6.5. This will keep the potential precipitates in solution and prevent subsequent blockage of emitters. Phosphoric acid is usually incorporated into the fertilizer program as a source of phosphor (P) while being used to lower the pH of the irrigation water.

Table 5. Factors causing dripper blockage

Type	Common name	Treatment
Biological	Algae Red iron sludge Slimy bacteria Organic material	Chlorination & Hydrogen Peroxide
Chemical	Iron or manganese sulphides Ca or Mg carbonate precipitation Any inorganic material	Acid injection
Physical	Root intrusion Silt & clay particles	Herbicide injection Flushing

3.4 Algae, organic bacteria

The presence of organic matter in water can be treated with the use of chlorine as a water purification agent. These algae and bacteria growing inside pipes are killed with very low concentrations of chlorine and should be flushed out after treatment.

Hydrogen Peroxide is a more aggressive cleaning agent which not only kills bacteria, but also cleans the precipitates and sludge from pipe walls, filters and drippers.

Regular treatment with Peroxide is probably the best practice to prevent blockages of drippers.

3.5 Root intrusion

Where dripper lines are used sub surface, and sometimes also above ground, root intrusion can be a big problem if not prevented or treated. Specific herbicides are registered for use in drip systems to stop root growth in the dripper as well as in the immediate vicinity of the dripper. With sub surface drip systems application of the herbicide should be a standard procedure on the maintenance schedule.

Note: *Chemical cleaning of drip systems is discussed in detail in Chapter 4: Irrigation Water Management (Fertigation).*

4 Micro Sprinklers

In micro sprinklers regular visual checking of sprinkler operation is very important. Ensure sprinklers are upright and operating in weed free conditions to ensure good distribution.

Table 6. Maintenance schedule for micro irrigation systems (manual control)*

Action	With each cycle	Monthly	Annually
Inspect system for leakages	•		
Check system pressure and flow rate	•		
Flush laterals (depending on water quality)		• (or weekly)	
Service air valves and pressure control valves			•
Check hydraulic and electrical connections			•
Check functioning of hydraulic valve on filter bank and inspect moving parts			•
Chlorine treatment (depending on water quality and method of application)			•
Take water simple at the end of the system and evaluate water quality changes			•

** The recommended maintenance schedule can be adapted for automated systems; e.g. system pressure can be monitored monthly*

Check for blockages. Insects often cause blockages or partly blocked nozzles, which cause poor water delivery and distribution. Nozzles should be cleaned by water pressure or blowing from the outlet side to remove the blockage. This is usually a grain of sand or parts of insect bodies but can also be algae or iron and manganese bacterial slime. In some cases blockages are caused by carbonate sediments. Check sprinkler output and uniformity.

While the system is operating check the sprinkler pressures in at least two places in a block by using a pressure gauge. Pressure variation should not be greater than approximately 10% of the average pressure over the block.

Activity

Activity 1

Small group activity

1 What measures can be taken to ensure the efficient working of a centre pivot's gear boxes?

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....

....

2. What can be done to increase the water application efficiency of a centre pivot system?

....

....

....

....

3. Discuss the maintenance schedule described for centre pivots. Which factors influence the implementation of this schedule by irrigation farmers?

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4. What is the first and basic action to ensure that dirt is not accumulated inside dripper lines?

....

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4. Water with high pH often causes carbonates to precipitate in irrigation systems. What kind of chemicals can be used to prevent this?

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My notes............

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Authenticator: Dr P Reid.

Technical Learner Guide

Irrigation Engineering

Level 5

Module 3

Evaluation of irrigation systems

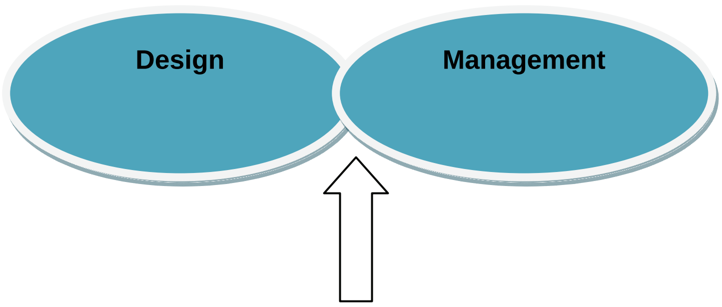
Study objective

After completion of this module, the learner should be able to have a basic understanding:

- To interpret a designer report on a proposed irrigation system
- To help a farmer to identify what questions to ask after receiving of a designer report
- Different components of an irrigation system and which performance criteria to evaluate after installation of irrigation system
- Water use efficiency vs. irrigation efficiency
- Wetting patterns of sprinklers and emitters
- Distribution uniformity
- Mean application rate
- Gross application rate
- Objective for the evaluation of an irrigation system
- Influence of too low a or too high pressure of an irrigation system on the wetting pattern
- Four general steps to take into consideration with evaluation of an irrigation system
- How to evaluate a sprinkler irrigation system regarding discharge and distribution uniformity
- How to evaluate a moveable irrigation system like a centre pivot, linear irrigation system regarding discharge and distribution uniformity
- How to evaluate a micro irrigation system regarding discharge and distribution uniformity

Table of contents

The evaluation of the irrigation system on the farm is an activity that should be done regularly to assess the level of performance and to detect problems as early as possible. The control valves should regulate the pressure and flow of the system correctly, filters should effectively remove the impurities, and pump stations should supply water irrigation water at the correct pressure ad flow at the lowest possible power requirements. The field evaluation of an irrigation system is an activity that is done periodically, and this is where the irrigation extensionists should have a workable knowledge of executing some of the field tests.



SUCCESS

The successful functioning of an irrigation system is a function of the correct technical and agricultural design together with the correct evaluation and management of the system. A complete manual for the evaluation of in-field irrigation systems are found in the ARC IAEs Manual for the Evaluation of irrigation Systems (www.arc.agric.za). This module will first of all have a look some of the questions that a producer should ask the designer of an irrigation system before installation of a specific irrigation system, and then this are followed with the basic evaluation procedure to determine whether an irrigation system is correctly installed. The third part of the module will focus on the evaluation of the various irrigation systems.

1. Evaluation of the design report

Many of the irrigation producers do not know what the requirements are when an irrigation consultant design an irrigation system. The role that the extensionists should play in this regard is imperative, and he/she should be able to help the farmer to ask the relevant questions to ensure that the correct design procedures are followed, which will enable the dealer to install the irrigation system correctly.

The following information should be provided by the irrigation consultant[8)]:

- **Layout plan**

This should comprise of the layout of the blocks and detailed plans of each block. Two copies are required, one for installation purposes and one for the producers records.

- **Cost estimation**

An estimation of the costs for the whole project must be made and for each phase, if applicable.

- **List of quantities**

A list of the items required for each block is needed so that quotations can be obtained from irrigation equipment suppliers. The list of quantities can also be used as a checklist for the equipment that is delivered by the irrigation equipment supplier.

- **Detailed drawings of equipment to make installation easier**

Valve connections: Drawings of the values with the desired accessories.

Filter banks: Drawings of the complete filter installation with manifolds and valves.

Pumps: Drawings of the pump with necessary equipment.

- **Pump curve**

The producer uses a pump curve, on which the duty point is indicated, to easily read off the efficiency and power requirement of the pump. The pump curve is also needed in case the existing irrigation scheme is expanded in the future.

- **Final technical report**

The report describes the resources that form part of the irrigation development as well as a short description of the operation of the irrigation system.

- **Maintenance and management manuals**

A thorough manual is required to ensure that the performance of the installed irrigation system is not adversely affected by incorrect practices.

- **SABI peak design form**

Technical design specifications which meet the design. The producer can use this information to decide if the design satisfies the set design specifications.

It is suggested that all this information is placed in a file to keep it for the future. The name of the producer, block name and contact details of the designer can be displayed on the cover of the file.

The following questions should be answered after the design report was received (Table 1).

Table 1. Questions to be ask by producers to the designers[8,9)]

Subject	Question	Where in design report can answer be found?
Expertise level of designer	What is the expertise level of the designer, e.g. Is the designer an approved SABI designer, or a professional registered engineer/technician?	Plan, Peak design form
General system information	What is the expected lifespan of the system? What safety factors are built into the system? Is expansion of the system possible? What additional equipment must be available on the farm for replacement of faulty equipment?	Technical report

Subject	Question	Where in design report can answer be found?
Description of proposed irrigation system	What are the soil water characteristics of the soil to be irrigated? What type of irrigation systems are used for the irrigation of the different crops? What type of emitter is proposed and what is the recommended working pressure, spacing and discharge of the emitter? What is the capacity and quality of the water source available for the development? Is the water suitable for irrigation of the specific crop?	Technical report
Designer parameters	What design parameters are used? What is the flow velocity in the main line? What is the recommended working pressure at the block inlet? What is the design CU/DU_{lq}/EU? Is the gross application rate of the system less than the infiltration rate of the soil?	Peak design form, technical report
Scheduling planning	How much easily available water is available in the root zone? What is the irrigation requirement of the different crops to be irrigated? What is the cycle length and standing/revolution time of the system? What is the system capacity (MM/day) and how does it compare with information obtained from the crop specialist?	Peal design form, technical report

Subject	Question	Where in design report can answer be found?
Equipment	Is a pump curve provided on which the duty point is indicated? How long is the pumping time within the ESKOM peak tariff time? What is the energy cost per year? Is filtration necessary and if so, what type is provided? Are injection pumps provided and if so, what is the capacity thereof? Is a flow provided and what are the requirements for its installation? Has provision been made for sufficient air inlet and outlet valves in the system? Is water hammer a problem and what can be done to prevent it?	Technical report
Guarantees	What are the guarantees of the individual components of the system and what is included and excluded? What is the guarantee that the system will function according to the design parameters? What is the availability of the proposed irrigation equipment when faulty equipment has to be replaced? What is the easily available water in the effective root area? Who and how will it be determined whether the system complies with the design specifications – e.g. how can it be evaluated? What equipment should be kept as emergency equipment? Is a written agreement provided in which it is confirmed that the system conforms to the SABI norms and if not, where do deviations occur?	Technical report

2. Evaluation of new irrigation system after installation

The following performance criteria should be addressed by the irrigation farmer after the new irrigation system was installed and is functioning (Table 2). This evaluation can also be conducted by the producer on an annual basis to identify possible problems in time.

Table 2. Proposed basic evaluation procedure to determine whether an irrigation system is correctly installed and functions according to design specifications[8,9)]

Subject/Item	Measurement/Evaluation	Action if measurements/evaluation does not conform to the design specifications
Inlet pressure of block	Determine the inlet pressure of the blocks with a pressure gauge and compare with the required pressures as specified on the peak design form	Contact designer and adjust set-up schedule if necessary
Emitter pressure and discharge	Measure pressure with a pressure gauge and measure the discharge in a container for at least five minutes at the four emitters on four corners of the field.	If a pressure variation of more than 20% of the design pressure or a discharge variation of more than 10% occurs, as specified in the technical report, contact the designer.
System lay-out	Examine system layout by measuring the distance between emitters/laterals, as well as the position of valves with a tape measure. Compare installed pipe diameters with those on the plan. Also take note of the direction of the laterals/emitter lines. If lateral is installed in the wrong direction, then the slope of that lateral is not as per design.	Re-install according to plan
Equipment: model and manufacturer	Compare the model/manufacturer of the installed pump, electric motor, filter and emitters with the specifications as per design report.	Contact designer for replacement of faulty equipment
Pump suction side fittings	Examine if the measurements of the suction pipe is according to plan and if the shape of the reducer, bend and adapters are correct.	Contact designer for replacement or re-installation of faulty equipment
Pump duty point	Determine the pump pressure by reading the pressure from the pressure gauge at the delivery side of the pump and compare with the pump pressure height specified on the peak design form. Determine the pump delivery	Contact designer for fault detection

3. Evaluation procedures applicable for the on farm irrigation system

The aim of efficient irrigated agriculture is to get maximum production for the same or less input. For example, growing more or better quality crop with the same or less amount of water. One measure of efficiency relates product to unit of water applied. For example, tonnes of product per cub m (m 3) of water applied. This is called **water use efficiency.**

Definition

Water use efficiency: This measure of efficiency combines system, crop, and agronomic aspects.

Irrigation efficiency is the percentage of water that actually gets into the soil and is used by the crop, compared with the amount supplied to the system.

The amount or volume of water available for irrigation is a major limitation to our ability to water crops and pastures. Over-irrigating or irrigating inefficiently not only wastes water but also money and adversely affects the environment. Consider the cost of unnecessary pumping and or nutrient wastage (particularly with fertigation).

There are many ways of assessing the efficiency of the components of an irrigation system. To determine the rate and uniformity of water application, we:

- Calculate the mean application rate (MAR)
- Calculate the evenness of application at various points in the system (that is, the distribution uniformity, DU)
- Measure the pressure and flow at various points in the system and compare this to the manufacturer's data
- Compare this to the soil infiltration rates

This information will indicate the application efficiency of our irrigation system. That is how well we are applying water to our fields. In order to evaluate the efficiency of our whole irrigation system we will however, need to also investigate the pump, pipelines, valves, supply, drainage, and other associated components of the irrigation system.

The following standard evaluation procedures have been developed by the ARC-IAE (Table 3) and the action proposed depends on conformation to the design specifications

Table 3. Basic evaluation procedure of an irrigation system components [8.9)]

tem/subject	Measurement/evaluation	Action
Inlet pressure of block	Determine the inlet pressure of the blocks with a pressure gauge and compare with the required pressured a specified on the peak design form	Contact designer and adjust set-up schedule
Equipment: model and manufacturer	Compare the model /manufacturer of the installed pump, electric motor, filter and emitters with the specifications as per design report.	Contact designer for replacement of faulty equipment
Pump suction side fitting	Examine if the measurements of the suction pipe is according to plan, and if the shape of the reducer, bend and adapters are according to the minimum standards.	Contact designer for fault detection.
Pump duty point	Determine the pump pressure by reading the pressure from the pressure gauge at the delivery side of the pump and compare with the pup pressure height specified on the peak design form. Determine the pump delivery by comparing the reading on the flow meter and compare it with the design flow rate.	Contact designer for fault detection.
Pump cavitation	Determine whether the pump cavitates by listening and feeling for excess vibration.	Contact designer for fault detection.
Schedule of blocks/moveable sprinklers in simultaneous operation	Compare the blocks/sprinklers that are in simultaneous operation, with the specification as suggested in the design report.	Change the blocks/sprinklers that are in simultaneous operation, by either opening the correct taps or reprogramming the irrigation computer.
General installation	Examine if any leakages occur in the system.	Repair leaks.
Operation of equipment	Examine operation of filters (e.g. pressure loss and back flushing action), air and pressure control valves.	Contact designer for fault detection.
System capacity	Determine system flow rate by taking the reading from the flow meter/measuring notch.	If a flow rate deviation of more than 10% from the average occurs, as specified in the peak design form, contact designer.

This evaluation matrix will help to identify possible areas where repairs or attention is required, and should be read together with the tables provided in Modules 1 and 2 where trouble shooting advice on various components of the irrigation system was provided.

4. Evaluation parameters of the performance of irrigation systems

The evaluation of the irrigation system is very important as far as management is concerned, especially to identify how effectively the water is applied to the crop. The application which is measured must be compared to the design application in order to determine the operation of the system, to be able to make the necessary adjustments. The objectives with the evaluation of an irrigation system are[10)]:

- To determine if the system is working according to farmers' assumptions and design specifications in terms of the water applied, and to provide a basis for improved irrigation scheduling.
- To determine how much variation there is in the amount of water applied and whether or not the measured variation has a significant impact on crop yields, drainage and runoff losses, fertiliser use efficiencies and production costs.
- To determine the causes of the variation in applied water and to investigate and recommend effective remedial actions
- Assess whether or not the conveyance system is sized within the deign norms that were based on a fair balance between capital and operating costs.
- Check efficiency with which power is being used
- Produce recommendations to improve on any of the aspects that would influence the efficiency of water and energy use.

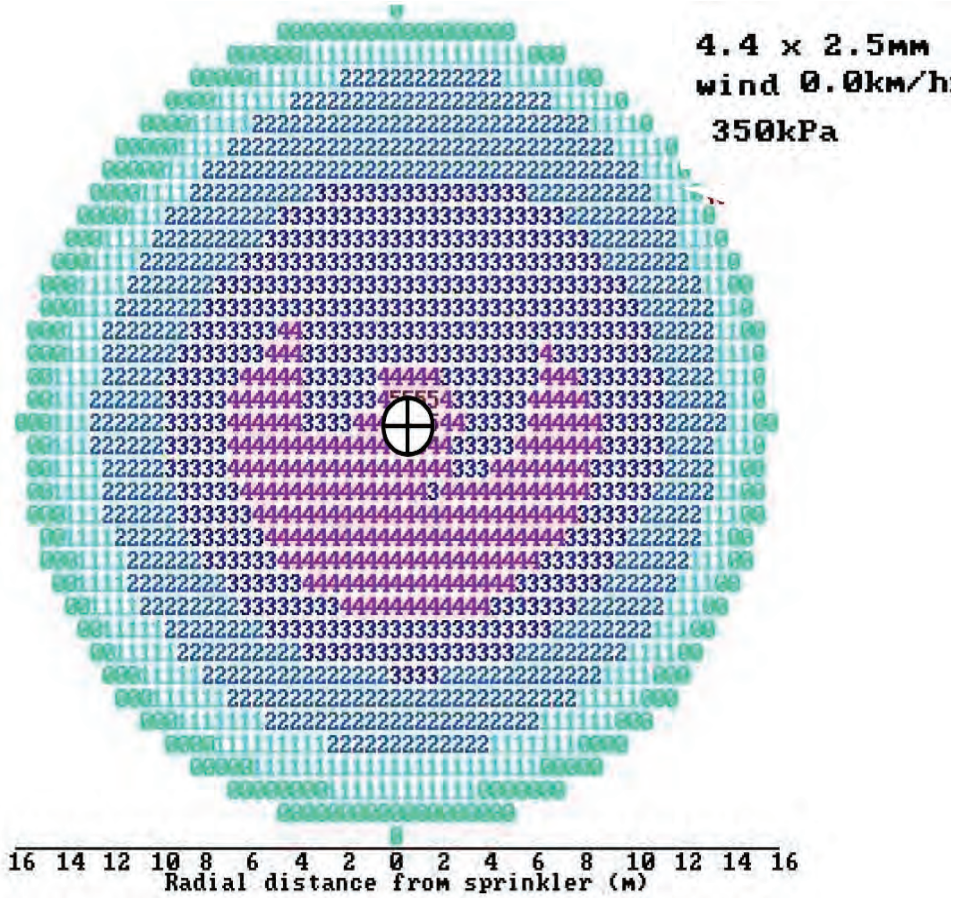
The following methods of evaluation of various types of irrigation systems are described in detailed in the Manual for the Evaluation of Irrigation Systems[9)], and therefore the intention is to highlight some the methodologies applied to the different irrigation systems.

Irrigation efficiency in the field is determined by the evaluation of:
- Conveyance efficiency
- System efficiency
- Field application efficiency

4.1 Wetting patterns for sprinklers

With the exception of drippers and specialised nursery nozzles, the general wetting pattern of sprinkler/emitter is circular. However, the amount of water over this wetted area will vary greatly.

That is not all of the wetted area receives the same amount of water. In Figure 1, we can see how the amount of water decreases as we move away from the sprinkler/emitter at the centre of the wetted area.



Note: the numbers of this chart represents the amount of water falling at that point in millimetres per hour

Figure 1. Wetting pattern of sprinkler and emitter[11)]

This means that the area covered by the sprinkler or emitter does not equal amounts of water. If we take a cross section of the sprinkler distribution, the following pattern of the nozzle is illustrated.

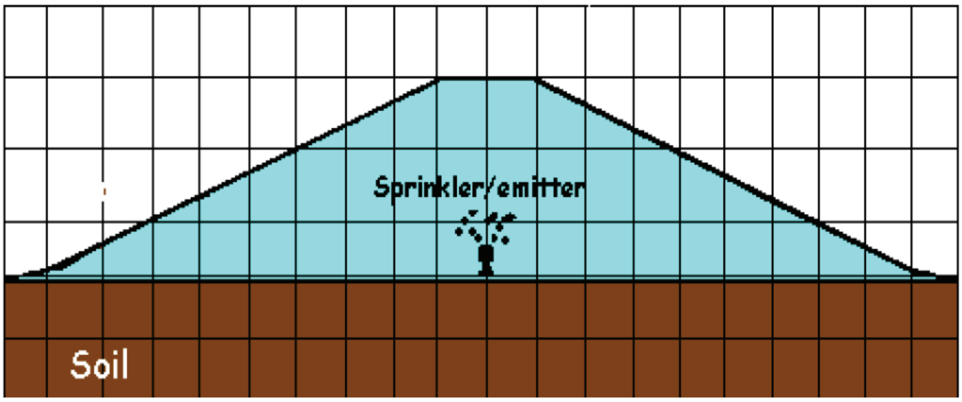


Figure 2. General soil wetting pattern from a sprinkler /emitter

To achieve an even distribution of water, an overlap of the wetting patterns of sprinklers should exist, which results in an even amount of water over the irrigated area. The total amount of water received in the overlapping areas is similar to the highest amount received near the sprinkler/emitter.

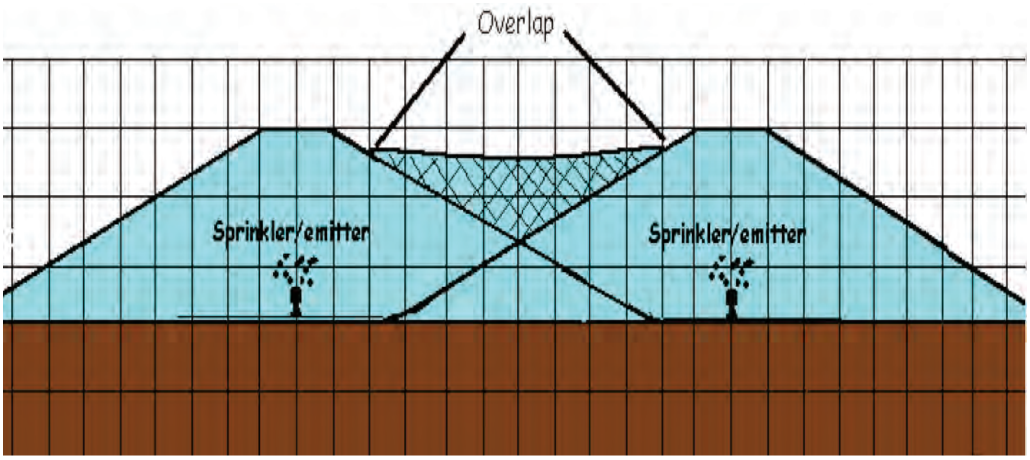


Figure 3. Overlapping wetting patterns of sprinkler to produce a uniform application of water

In order to determine the efficiency of an irrigation system we need to determine how much water is applied and how well it is distributed. The two terms that is generally used to describe the application rate and the uniformity of the irrigation system are mean application rate (MAR) and distribution uniformity (DU). It is important to calculate these for a specific irrigation system.

4.2 Distribution uniformity (DU)

Definition

Distribution uniformity (DU) is often expressed as a percentage, gives an indication of how evenly the sprinklers/emitters are operating or overlapping. The higher the DU, the more evenly the irrigation water is distributed. A DU greater than 75% is most acceptable for the most sprinkler systems. Drip irrigation systems should have a DU greater than 95%.

The MAR and DU indicate how well the irrigation system is supplying water to the crop. If however through evaluation tests it is discovered that the system is performing below the acceptable norms, it is important to identify the possible causes for this. The MAR and DU may be effected by the wear of sprinklers and emitters, and with overlapping

$$\textbf{Distribution uniformity} = \frac{\textbf{Average lower quarter depth of water}}{\textbf{Average depth over whole field}}$$

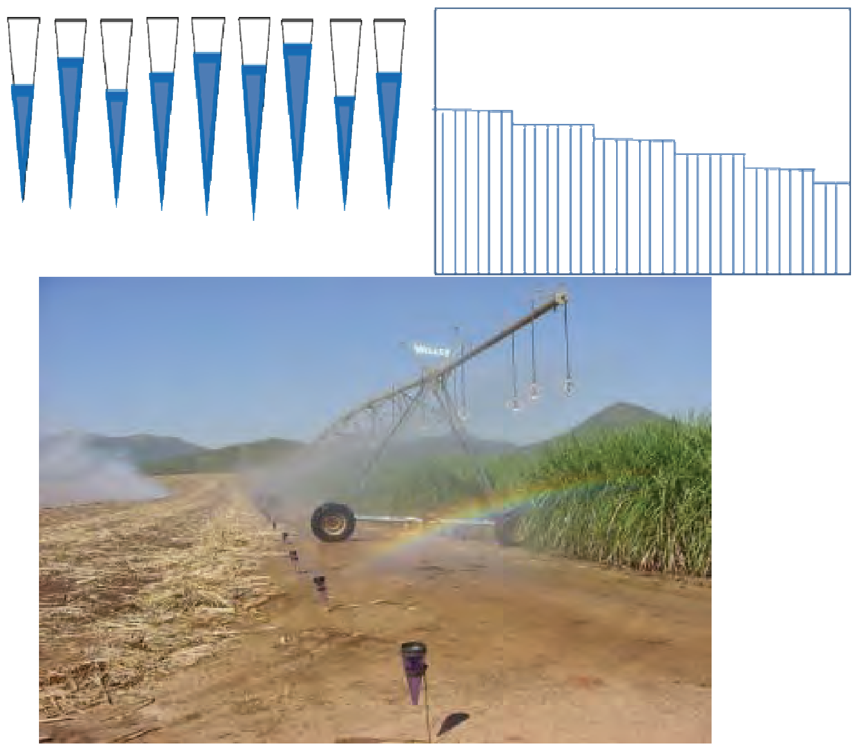


Figure 4. Measuring uniformity with rain gauges[9)]

4.3 Mean Application Rate (MAR)

Definition

The **mean application rate (MAR)** is the average rate (in mm/h) that irrigation water is applied to the wetted area of the soil. It is very important, that the MAR does not exceed the soil water infiltration rate

With moveable irrigation systems the situation is different as the machines moves over the field. In this case the instantaneous application rate (NOT THE MAR) must not exceed the infiltration rate of the soil. Increasing travel speed of a centre pivot will not reduce the instantaneous application rate.

Gross application rate (GAR) = Sprinkler discharge ($q_{e)}$/wetted area (A)

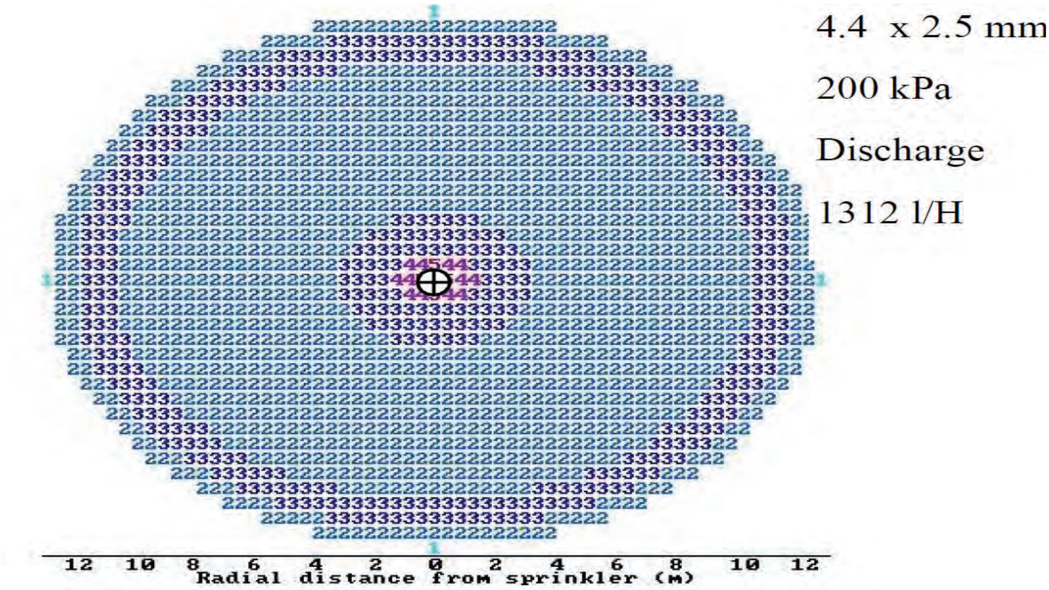
- **Sprinkler discharge (q_e) = $\frac{\text{container size in litres}}{\text{time to fill container in seconds}}$ x 3.6**

4.4 Pressure and flow rate

Incorrect pressures and flow rates are common causes of system inefficiency. It is therefore important that an irrigation system is run at the designed pressure. The operating pressure can dramatically affect the sprinkler/emitter wetting pattern and output, and therefore the irrigation efficiency of an irrigation system. This is because the sprinkler/emitter is manufactured to create specific size droplets and wetting pattern at the designated pressure.

Figure 5. Measuring of operating pressure of sprinkler irrigation system

If a sprinkler/emitter is operating at below the required pressure, large droplets are formed which tend to be thrown further than small droplets. This influence the wetting pattern of a sprinkler, and a typical"doughnut ring" shape is developed.



Note: The correct operating pressure for this nozzle is 350 kPa

Figure 6. Operating pressure too low [11)]

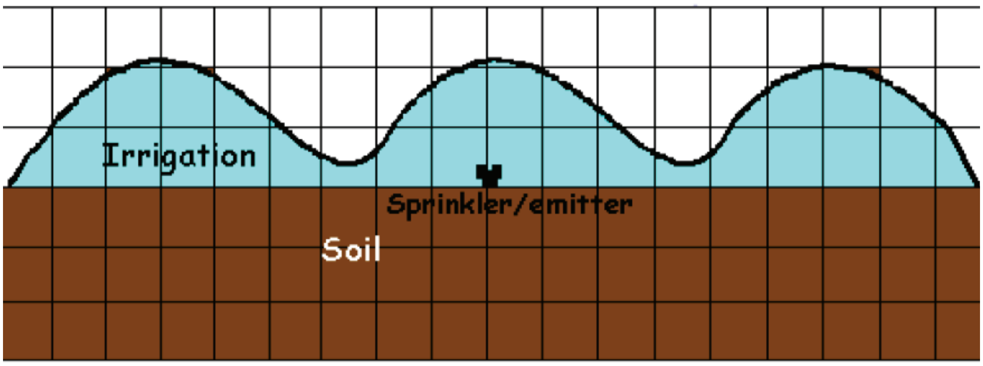


Figure 7. Pressure too low

Operating of an irrigation system below the specified pressure will result in areas receiving too much water, while other areas receive too little water (Figure 7). This has also the potential to reduce the crop production, while at the same time it has the potential to waste irrigation water.

Where an irrigation system is operating above the specified pressure, it will cause also irregular wetting patterns. If the pressure is too high, the droplets are very fine and create even a fine mist that could drift with wind.

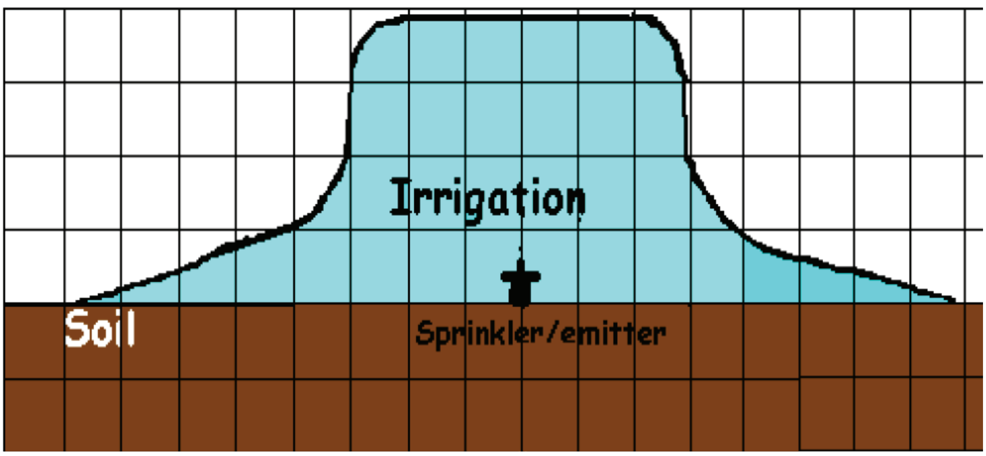


Figure 8. Pressure too high

Operating at pressures above the recommended pressure may leave areas under-watered, while others receive more water. The acceptable norm for variation in pressure is ±10%, and a flow variation of greater than ±5% is unacceptable.

4.5 System evaluation

The following four general steps apply with the evaluation of any type of irrigation system[11)]:

Step 1: Check components

Before taking any measurements, a general physical check of all components should be done to make sure the system is operating as correctly as possible. Check that no leaks or suction problems occur, and that the number of outlets operate correctly, and their size and pressure match the system design.

Step 2: Measure pressure and flow

Check the pressure and flows against the specific pressure and flow charts for the specific irrigation system. It may occur that the output and distribution at one point is correct while at another adjustments are required. This may be because of:

- Different supply main and hydrant is being used than prescribed
- Hydrant is not set correctly (these can be adjusted to adjust pressure)

Note: One way of checking pressure of a whole system, which include drip, is to measure "near", "far", "High" and "low" points on the complete system. With moveable irrigation systems it is also important to check the pressure when the machine is at a high and a low point.

Step 3: Measuring mean application rate (MAR)

To measure MAR, catch cans or rain gauges are placed in the irrigated test area and the amount of water (l) collected is measured, converted to a depth in mm, and divided by the number of cans to give MAR in mm/h.

MAR = Total depth (mm) collected in catch cans per hour/ Number of catch cans

For drip irrigation systems, the procedure varies slightly. The output from the individual dripper is collected over a measured time, and the amount collected is divided by the wetted area.

Dripper MAR = Volume collected from dripper/Average wetted area

The results then need to be converted to an hourly basis. Therefore the number of minutes the test was run is multiplied by 60 to get the "per hour" rate.

Note: If the MAR exceeds the soil infiltration rate, adjustments are required to reduce MAR.

Step 4: Measuring distribution uniformity (DU)

When all volumes have been converted to depths, the lowest 25% are selected. The average of the lowest 25% is divided by the MAR to give the DU figure.

DU= average depth of the lowest 25% of cans / MAR

Note: For drippers, use the volumes of the lowest 25%of drippers being checked. Non overlapping systems by nature do not require distribution uniformity (DU).

Activity

Activity 1

Small group activity

1. What should be addressed in a design report for a newly proposed irrigation system?

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2. Discuss the various components of an irrigation system and identify the most important performance criteria as per system component that should be evaluated on a regular basis.

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3. What do you understand with the following concepts?

- Irrigation efficiency
- Water use efficiency
- Wetting pattern of a sprinkler or emitter
- Distribution uniformity
- Mean application rate

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4. What are the objectives with the evaluation of an irrigation system?

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5. Discuss the factors that influence irrigation efficiency?

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6. Incorrect pressures and flows or irrigation systems occur frequently and influence irrigation efficiency. Explain the influence of the following deviation of system pressure on the wetting patterns of sprinklers and emitters:

- Too low pressure
- Too high pressure

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7. Discuss the four general steps that you as an extensionist should follow in the evaluation of an irrigation system?

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5. Sprinkler systems

The evaluation methods and procedures for sprinkler, permanent sprinkler, side roll and floppy irrigation systems are the same, and therefore it is discussed in this module as sprinkler irrigation, except where clear differentiation is made between the various systems.

The following general information is important to collect before the official test in the field should start:

i) Record the information as illustrated in Table 4.
ii) General impression of irrigation and management system- condition of pipes (leakages or rust), and other equipment, vertical alignment of standpipes and sprinklers, condition of foot piece of dragline sprinklers.
iii) Select a representative test block in the field and draw a layout of the total system:
    a. Irrigation field and its boundaries
    b. Position of the test block in the field
    c. Position of main pipelines, laterals, manifolds, sprinkler lines and sprinklers
    d. Position of hydrants and the lines which serve them
    e. Position of pump station
    f. General terrain slope and the direction thereof
    g. Position of crops around the rain gauges and the height of crops
iv) Peg out the test block and place the rain gauges according to the appropriate method
v) Connect all sprinklers as for normal operation and switch the system on
vi) Record the wind speed and direction, as well as relative humidity and temperature readings

vii) Measure the pressure at the hydrants

viii) At each sprinkler or nozzle, which is identified according to the guidelines in the system, the following observations and measurements are done:

a. Type and name of sprinkler
b. Nozzle size as printed on the nozzle
c. Is a pressure regulator in use or not?
d. Vertical alignment of the standpipe
e. Height of the stand pipe
f. Measure of the sprinkler nozzle size
g. Measure of sprinkler's operating pressure
h. Measure the sprinkler discharge

ix) Go to the pump station and the distribution system (pipe and valves) and apply the necessary tests and troubleshooting as discussed in previous modules.

Table 4. General information on the irrigation system and management

Soil information	
Type (texture)	
Depth (m)	
Crop information	
Crop under irrigation	Type
	Cultivar
Area under irrigation (of specific crop)	
Planting date	
Planting spacing (m x m) or plant density (plants/ha)	
Expected yield (t/ha)	
Water information	
Water source	
Water quality	
Scheduling information	
Scheduling method	
Gross application per cycle (mm/day)	
Cycle length (days)	
Standing time (h)	
Calculate gross application per month and compares with gross irrigation requirement for peak irrigation month	
Gross application per month (mm): (Gross application per practical cycle (mm) x days in month)/ Practical cycle length (days)	

5.1 Pressure measurement

a. Pressure at hydrant

Test the pressure at the delivery side of the hydrant and compare it to the designer's specifications. It was found in practice that the optimal operating pressure (kPa) of the sprinkler is between 66 and 70 times the nozzle diameter (mm). This is applicable to nozzles of 3-7 mm diameter.

Table 5. Optimal operating pressure versus nozzle diameter for sprinklers[9)]

Nozzle diameter		Operating pressure (kPa)	
mm	inches	x 60	x 70
1,59	1/16"		
1,98	5/64"		
2,38	3/32"		
2,78	7/64"		
3,18	1/8"	191	222
3,57	9/64"	214	250
3,97	5/32"	238	278
4,37	11/64"	262	306
4,76	3/16"	286	333
5,16	13/64"	310	361
5,56	15/64"	333	389
5,95	15/64"	357	427
6,35	1/4"	381	445

b. Pressure at sprinkler

The pressure at the sprinklers must be measured with a pressure gauge (0-500 kPa), fitted with a pitot tube (Figure 6). The sprinkler operating pressure on the same line/block should deviate less than 20% of the average pressure. The sprinkler operating pressure must be approximately 60-70 times the nozzle diameter (mm).

5.2 Discharge tests

a. Sprinkler nozzle size

Observation of wear on sprinkler nozzles is measured with a specially machined device as illustrated in Figure 9. It is important that the device should have a scale of at least 0.5 mm. The measurement shows the amount of wear (mm) on the sprinkler nozzle. If the wear is more than 5%, nozzles must be replaced. An increase of 55 in wear means an increase of 10% in discharge and power demand that implies additional operational costs and over irrigating.

Figure 9. Measuring device for sprinkler nozzle size (Source: F Reinders)

b. Sprinkler discharge

Test the discharge of sprinklers in a container with a hose pipe connected to the sprinkler nozzle (Figure 10).The minimum size of the container should be 20 l and a stopwatch must be used to record the time it takes to fill the container. The open end of the hose should not be held under the water in the container, but also not so high that water splashes out of the container.

Figure 10. Measuring of sprinkler discharge[9)]

For complete evaluation, measurements must be taken at least at the following positions in the irrigation block:

- At the four corners of the lateral closest to the pump house
- First and last position on the lateral furthest from the pump house
- First and last position on the lateral which is situated highest in the field
- First and last position on the lateral which is situated lowest in the field

5.3 Distribution tests

The distribution of a sprinkler is influenced by the drop size, wind strength, relative humidity and operating pressure of the system

a. Distribution uniformity (DU)

Rain gauges (at least 25) are placed on a grid as illustrated in Figure 11 between two adjacent lines and sprinklers. The top of the rain gauge must not be more than 300 mm above ground surface or above the height of the crop. For non-permanent systems with a 18 x18 m spacing, 36 meters are placed, so that each meter covers an area of 3 x 3 m in the block. The distance at which the rain gauges are placed from the boundary lines of the block is 1.5 m and the spacing in the block is 3 m. The placing of rain gauges in an irrigation block serves only as a guideline .This type of test is usually taking 1-2hours, during which water is collected in the rain gauges.

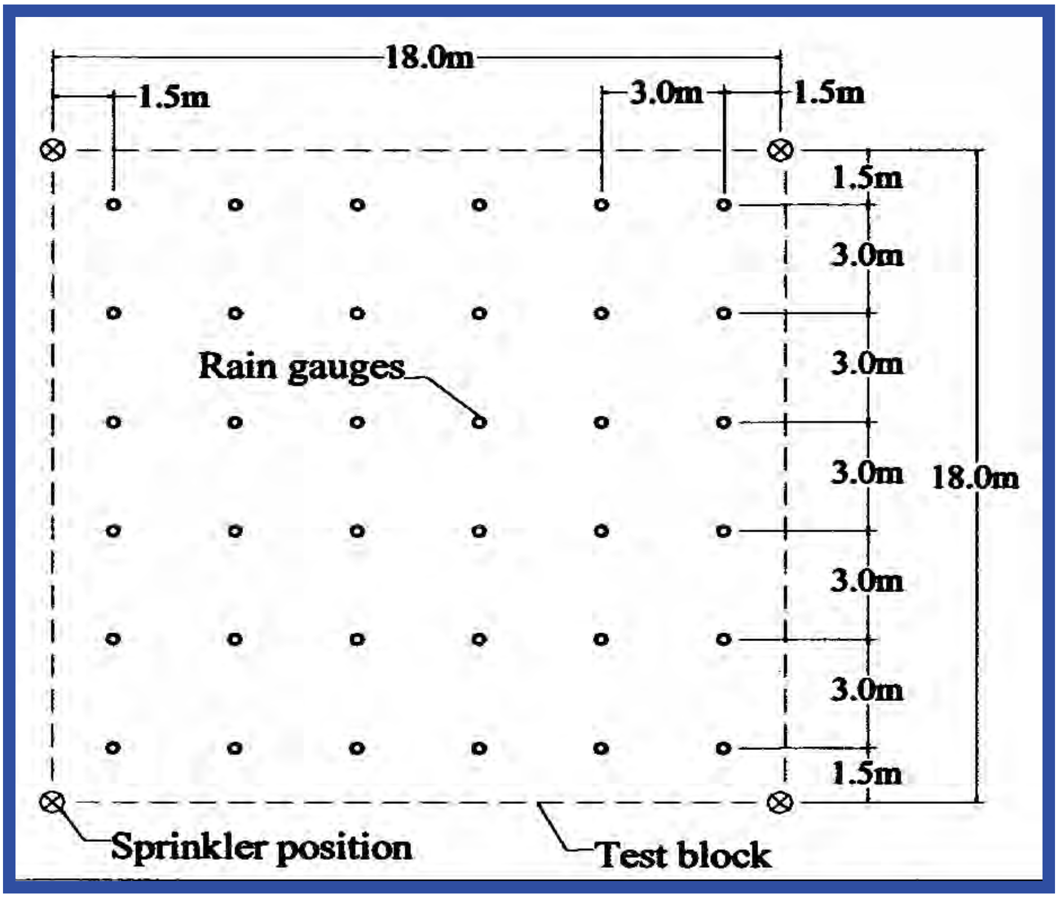

Figure 11. Rain gauge set-up at sprinkler system to measure distribution

After completion of the test, the readings are taken and the rain gauge readings are then used to determine the DU value.

$$DU_{lq} = \frac{\text{Average application (lowest 25\%)}}{\text{Average application (total system)}} \times 100$$

A DU value less than 60% is unacceptable and a value of more than 75% is recommended.

Activity

Activity 2

Small group activity

1 What general information about a sprinkler irrigation system is required before the official discharge and distribution tests are conducted in the field?
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2.a. Explain the in-field evaluation methods you will follow to measure the discharge of a sprinkler or nozzle?

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b. Explain how you will conduct a distribution uniformity test for sprinkler irrigation systems in the field?
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6. Evaluation of moving irrigation systems

Moving irrigation systems include pivots, travelling boom and linear systems. The basic test procedures and standards for these irrigation systems are the same.

The following general information is important to collect before the official test in the field should start:

i) Record the following information as illustrated in the following table.

Table 6. General information on the irrigation system and management

Soil information		
Type (texture)		
Depth (m)		
Crop information		
Crop under irrigation	Type	
	Cultivar	
Area under irrigation (of specific crop)		
Planting date		
Planting spacing (m x m) or plant density (plants/ha)		
Expected yield (t/ha)		
Water information		
Water source		
Water quality		
Scheduling information		
Scheduling method		
Gross application per cycle (mm/day)		
Cycle length (days)		
Standing time (h)		
Calculate gross application per month and compares with gross irrigation requirement for peak irrigation month		
Gross application per month (mm): (Gross application per practical cycle (mm) x days in month)/ Practical cycle length (days)		

ii) General impression of irrigation and management system- condition of pipes (leakages or rust), and other equipment, vertical alignment of standpipes and sprinklers, condition of foot piece of dragline sprinklers.

iii) Sketch the lay out of the system and record the following:
   a. North direction
   b. Field slope
   c. Rotation direction of the centre pivot
   d. Wind direction
   e. Position of the rain gauges with respect to the towers
   f. Position of the pump house
   g. Position of the height of the crops

iv) Record all information from the control box of the centre pivot

v) Select a road or open strip where no crop interference will take place and place the rain gauges out according to the test procedure

vi) Switch the system on
vii) Record the wind speed and direction, as well as relative humidity and temperature readings
viii) Measure the length of the centre pivot as well as the overhang
ix) Record the type and size of the nozzles used, and whether they are fitted with pressure regulators
x) Measure the sprinkler discharge and take pressure measurements
xi) Determine the circumference of the last tower and the application rate of the last tower
xii) Go to the pump station and the supply system and apply the necessary tests and troubleshooting as discussed in previous modules.
xiii) After the system moved over all the meters, it is switched off and the readings in the rain gauges are taken and recorded.
xiv) The measured and obtained results are processed to obtain the following:
   a. Comparison between the system pressure as measured and the prescribed design specifications, as well as the different measuring points on the towers.
   b. Comparison between the system flow rate as measured and the prescribed design specifications, as well as the different measuring points on the towers
   c. Uniformity coefficients gives an indication of how evenly distribution of the irrigation water is within the irrigation block
   d. DU value is shown as a comparison between the lowest 25% of measurements and the average of all the measurements in the block
xv) Application efficiency (AE) value) that indicates how much water is efficiently reaching the soil
xvi) Travel speed of the centre pivot
xvii) Application rate of the last tower compared to the soil infiltrability rate
xviii) Application rate of the last tower compared to the infiltration rate of the soil
xix) From above general recommendations can be presented to optimise the operation of the system.

6.1 Pressure measurement[2)]

For centre pivots and linear systems, the pivot pressure must be measured and compared to the manufacturers' specification. The pressure is measured at beginning and the end of each tower with the pitot tube as described in the sprinkler irrigation. The pressure variations may not be more than 20% of the average pressure.

$$\Delta P = (P_{max} - P_{min}) \div P_{ave}$$

where:
ΔP = *pressure variation of measured pressure readings*
P_{max} = *maximum pressure (kPa)*
P_{min} = *minimum pressure (kPa)*
P_{ave} = *average pressure (kPa)*

6.2 Discharge tests

For centre pivots and linear systems the discharge of the nozzles must be measured at the beginning and the end of each tower with the container and pipe method, as described in sprinkler irrigation. The nozzles can be selected randomly. An increase in discharge from the beginning to the last nozzle will be observed. Verify the measured discharge values with the following equation[2)]:

$$q = \frac{2\,Q\,r\,L_e}{R^2}$$

where q =nozzle discharge [m³/h]
Q =system flow rate [m³/h]
r =distance from the centre to the specific nozzle [m]
L_e =nozzle spacing
R =radius of the total wetted area [m]
=span length + overhang + endgun effective radius

6.3 Distribution tests

Distribution patterns of how and where different nozzles of the centre pivot distribute water on the soil, is determine according to the measurements done. The following requirements are set for the rain gauges and /or catch cans:

- The collectors must be of the same size and shape
- Collectors must be shaped such that water cannot splash out at the top. Height of the collectors must at least be 120 mm and the inlet diameter half to one times the height, with a minimum diameter of 60 mm

The distribution tests at pivot points is executed by placing collectors at a spacing of about 30% the wetted band width of the pivot nozzles, or maximum 10 m , in a straight line on the radius of the centre pivot as illustrated in Figure 12. The spacing of the meters must be rounded of to the nearest 3 m, 5 m or 10 m. Usually when the farmer and the evaluator agree, no meter is placed in the fist 20% of the effective radius of the centre pivot. The effective radius is the radius from the pivot centre to the end gun plus 75% of the irrigation radius of the end gun.

Example

If the radius of the centre pivot is 300 m to the endgun and the endgun has an irrigation radius of 20 m, the effective radius is: 300 + (20x75%) = **315 m**

The first rain gauge is placed at a distance of: 315x20%=63 m from the centre of pivot.

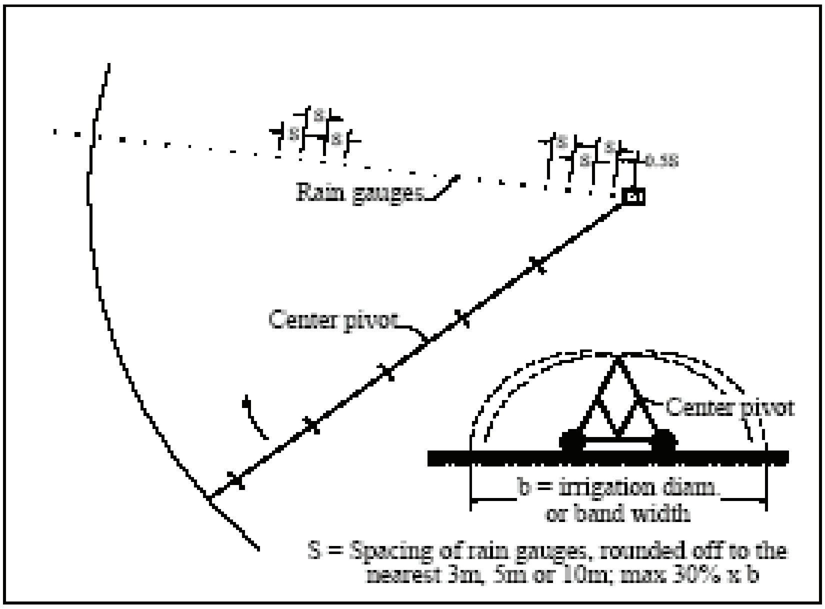

Figure 12. Placing of rain gauges for centre pivot evaluation[9)]

The following important guidelines should be adhered to during the evaluation of a centre pivot (American Society of Agricultural Engineers, 1977):

- Collectors must place such that the crop does not influence the measurements of the water application. Where crops are higher than the rain gauges, but lower than the nozzles, ensure an unobstructed space at least two times the distance between the height of the crop and the top of the collectors, on both sides of the collectors. Where the nozzles are lower than the crop height, a distance, without any obstruction, of 1.25 times the wetted radius of the nozzles must be maintained.
- Wind velocity and direction must be monitored and recorded at 15 minute intervals during the evaluation. The accuracy of the test is reduced when the wind speed exceeds 1 m/s, and the test should be stopped when the wind speed exceeds 5 m/s.
- Preferable that evaluation is done during conditions when evaporation is relatively low and has a minimum influence, i.e. early in the morning or during the night. Measure the relative humidity, dry-bulb and wet bulb temperatures.

The DU_{lq} value gives an indication of the extent of under irrigation that is taking place. A DU_{lq} value of less than 60% is not acceptable and a value of more than 75% is recommended for sprinkler irrigation, as guidelines for DU_{lq} value for centre pivots could not be found in the literature.

Activity

Activity 3

Small group activity

1. What general information about a centre pivot irrigation system is required before the official discharge and distribution tests are conducted in the field?

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2. Explain the in-field evaluation methods you will follow to measure the discharge of a sprinkler or nozzle of a centre pivot irrigation system?

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3. Explain how you will conduct a distribution uniformity test for sprinkler irrigation systems in the field?

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7. Evaluation of micro irrigation systems

Micro irrigation systems require high levels of management in order to ensure that water is used effectively. The system mainly consists of drippers and micro sprayers, and it is important that the evaluation of an entire block is done, to be able to identify problem if blockages occur.

Since the emitters have very small flow paths through which the water is flowing, blockages occur from time to time. Blockages occur because of poor water quality, and this should be kept in mind already during the designing phase.

The following general information is important to collect before the start of the official evaluation tests:

i) Record the following information as illustrated in the following table.

Table 7. General information on the irrigation system and management[2)]

Soil information	
Type (texture)	
Depth (m)	
Crop information	
Crop under irrigation	Type
	Cultivar
Area under irrigation (of specific crop)	
Planting date	
Planting spacing (mxm) or plant density (plants/ha)	
Expected yield (t/ha)	
Water information	
Water source	
Water quality	
Scheduling information	
Scheduling method	
Gross application per cycle (mm/day)	
Cycle length (days)	
Standing time (h)	
Calculate gross application per month and compares with gross irrigation requirement for peak irrigation month	
Gross application per month (mm): (Gross application per practical cycle (mm) x days in month)/ Practical cycle length (days)	

ii) Select a representative test block in the field and draw a layout of the total system:
   a. Irrigation field and its boundaries
   b. Position of the test block in the field
   c. Position of main pipelines, laterals, manifolds, sprinkler lines and sprinklers
   d. Position of hydrants and the lines which serve them
   e. Position of pump station
   f. General terrain slope and the direction thereof
   g. Position of crops around the rain gauges and the height of crops

iii) Install a flow meter in one of the laterals in the test block

iv) Measure the pressure at the hydrants and identified points on the laterals

v) At each emitter identified in the system, the following observations and measurements are done:
   a. Type and name of emitter
   b. Is the emitter fitted with a pressure regulator or not?
   c. Determine the discharge and distribution tests according to the guidelines

vi) Go to the pump station and the distribution system (pipe, filter station and valves) and apply the necessary tests and troubleshooting as discussed in previous modules.

vii) The following questions regarding management of the system should be answered:
   a. Is chemical spraying applied?
   b. Are preventative maintenance practices used-chlorinating and acid treatment
   c. What method of control is applied for filter flushing?

viii) General impressions of irrigation and management system-condition of the pipes (leakages and other equipment)

ix) Measured and observed results are processed and the following is obtained:
   a. Comparison between system pressure and the design specifications as well as between different hydrants and laterals
   b. Comparison between system flow rate a measured and the design specifications, as well a between different hydrants and laterals
   c. Coefficient of variation and the statistical uniformity for emitter discharge
   d. Emission uniformity

7.1 Pressure measurements

The pressure measurement at hydrant of the test block should be compared to the design specifications (Figure 13) The pressure on the laterals are tested with a pressure meter (0-300 kPa) as illustrate in Figure 14.The pressure variation in a test block should not exceed 20%, but this does not apply to compensated emitters, where it is important that minimum pressure provided to the emitter exceeds the manufacturers specifications.

Figure 13. Pressure measurement at hydrant[9)]

Figure 14. Pressure measurement in the lateral[9)]

It is also important to measure the pressure variation over the filters, before and after filters have been backwashed. Installed pressure meters are required for this exercise. The following norms apply for the pressure difference over different filter banks.

Table 8. Norms for allowable pressure difference over different filterbanks [12)]

Type of filterbank	Allowable pressure variation over clean filterbank (kPa)	Allowable pressure variation over filterbank before backwashing (kPa)
Ring/mesh filter	≤ 30 kPa	≤ 70 kPa
Sand filter with ring/mesh filter	≤ 40 kPa	≤ 60 kPa

7.2 Discharge tests

The discharge of the emitters is measured with a jug and stopwatch (Figure 15).

Figure 15.Discharge test of surface drippers (Source: F Reinders)

Take readings at five different laterals and at distances 0. L/4, L/2, 3L/4 and L on three laterals as illustrated in the following figure.

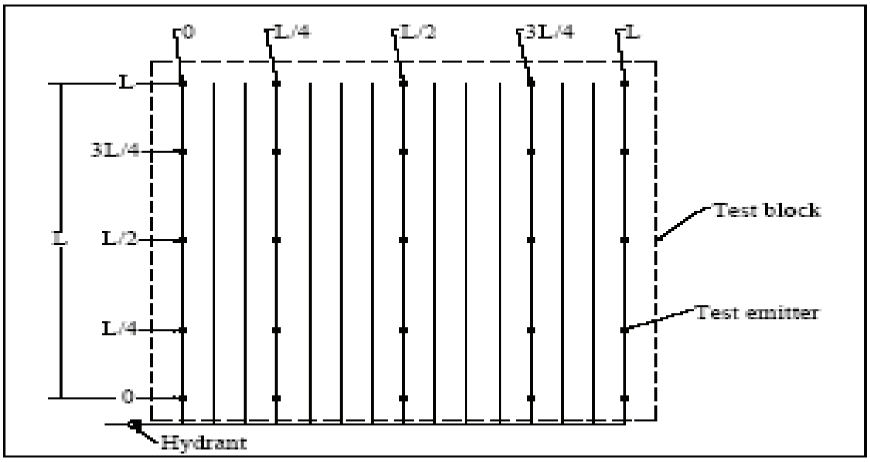

Figure 16. Position of testing points in a block for the discharge test

The flow in the system is measured by installing a flow meter in one of the laterals in the test block for the duration of the test. This is usually done at a fifth of the distance from the manifold where the pressure losses begin to stabilise, so that the flow rte can be compared to the design discharge of the emitters. The discharge variation must not exceed 10% from the average emitter discharge in the block.

7.3 Distribution tests

The distribution and uniformity of application of water in micro irrigation systems are determined by the hydraulic design, topography, operating pressure, pipe size, emitter spacing and the emitter discharge.

The discharge uniformity of micro irrigation systems is measured using the coefficient of variation according to the following equation[2)]:

$$CV = (S/\bar{x}) \times 100 = \left(\frac{\sqrt{\frac{1}{n-1} \times \sum_{i=1}^{n} \left| x_i - \bar{x} \right|^2}}{\bar{x}} \right) \times 100$$

where CV = coefficient of variation [%]
$\underline{S}$ = standard deviation
$\bar{x}$ = average discharge of all the testing points [l/h)
x_i = individual discharge measuring of each testing point [l/h]
n = number of testing points

Statistical uniformity of emitter discharge (Us)[2)]

The statistical uniformity of emitter discharge rate is calculated form the known CV value, using the following equation.

$$U_s = 100 \times \left(1 - \frac{CV}{100}\right)$$

Emission uniformity (EU)[2)]

The emission uniformity gives an indication of how uniformly the water is delivered to the plants and is calculated by using the following equation:

$$EU = 100 \times \frac{\text{Average discharge (lowest 25\%)}}{\text{Average discharge of the total block}}$$

$$= 100 \times \frac{m_{<25\%}}{\bar{x}}$$

NOTE: Support regarding the calculation of these values may be required from irrigation designers and experts in the field.

Once these values are available, the following guidelines could be used for the evaluation of the distribution uniformity of a micro irrigation system (Table 9).

Table 9. Guidelines for CV, Us an EU values[2)]

Classification	CV (%)	U_s (%)	EU (%)
Excellent	<10	>90	>87
Good	10-20	80-90	75-87
Fair	20-30	70-80	62-75
Poor	30-40	60-70	50-62
Unacceptable	>40	<60	<50

Activity

Activity 4

Small group activity

1 What general information about a micro irrigation system is required before the official discharge and distribution tests are conducted in the field?
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2. a. Explain the in-field evaluation methods you will follow to measure the discharge of an emitter of a micro irrigation system?

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b. Explain how you will conduct a distribution uniformity test for micro irrigation system in the field?
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My notes............

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Authenticator: Dr P Reid.

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