SABI NORMS FOR THE DESIGN OF IRRIGATION SYSTEMS

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DISCLAIMER:

Although the norms have been compiled with great care, SABI, its employees or representatives shall not under any circumstances be held responsible for any loss or damage to any person, object or organisation as a result of the application of these norms.

Background

A norm is defined as a widely accepted or required standard against which performance or achievement can be assessed.

The SABI design norms serve to guide the designer in calculations and decision-making in the planning and design of agricultural irrigation systems. The norms are presented under the following four main headings:

- System planning
- Irrigation systems
- Water supply systems
- Greenhouses and tunnels

The design of irrigation systems requires a balanced approach that results in both technically, financially and ethically acceptable solutions for the customer. Diverging from the norms is acceptable if it can be well motivated from both a technical and an ethical perspective by the designer.

1. System Planning

1.1 Suitability of irrigation systems

When selecting the type of irrigation system to be used in a specific situation, there are a number of factors that have to be taken into consideration. Although it is not possible to set fixed norms for the selection of irrigation systems, it is recommended that information regarding the following five aspects of the situation that the system is being designed for, should be collected and assessed:

- **Crop:** information should be collected on the cultivar, planting and harvesting date / growing season, row direction and spacing of plants, crop heights, tilling practices, climatic water requirements and any climate control requirements.

- **Soil:** an investigation of soil and analysis and interpretation of the data by a soil scientist is recommended. Factors such as texture, structure, infiltration rate, water holding capacity, soil depth and permeability should be taken into consideration, as well as crop specific requirements such as wetted leaves, dry leaves and stems, root development

- **Water:** both aspects of quantity and quality should be investigated. A hydrological study and confirmation from the water management authority are recommended to ensure adequate water is lawfully available. The water quality should be suitable for both the crop and soil of the specific situation, and may also require special treatment if a detrimental effect on the irrigation equipment is expected.

- **Climate:** the closest weather station should be identified in order to access long-term historical weather data such as evaporation, rainfall, temperature, humidity and wind, as these will have an influence on the water requirements and system orientation.

- **Site:** the size, shape and slope of the site available should be taken into consideration when selecting the irrigation system.

Table 1 has been compiled by the ARC-IAE to assist designers with the selection of the most appropriate type of irrigation system (Burger et al, 2003).

The following symbols are used in the table to indicate the degree of limitation or obstacles that might occur:

o	No limitation
x	Little limitation
xx	Moderate limitation
xxx	Severe
#	Requires further thorough investigation by an expert.

Table 1 Comparison between systems

Criteria	Flood	Sprinkler	Micro spray	Drip	Big gun / traveling irrigator	Centre pivot and linear move
1. Climate						
Temperature > 30□C	o	xx	xx	o	xx	xx
Relative humidity < 40%	o	xx	xx	o	xx	xx
Wind speed > 15 km/h	o	xxx	xxx	o	xxx	xxx
Rainfall < 300 mm/year	o	o	o	xx	o	O
2. Topography						
Earthworks > 250 m^3/ha	xx	o	o	o	o	O
3. Salinity						
Salinity > 2 000 ppm	x	xx	xx	xxx	xx	xx
4. Flow rate						
< 100 m^3/h	xx	o	o	o	x	xx
5. Water quality						
Turbidity (silt, fine sand)	o	x	xx	xxx	x	x
Lime, iron	o	x	xx	xxx	x	x
Algae	o	o	xx	xxx	o	o
6. Soils						
> 20% clay	x	x	xx	xx	xx	xxx

Criteria	**Flood**	**Sprinkler**	**Micro spray**	**Drip**	**Big gun / traveling irrigator**	**Centre pivot and linear move**
10 - 20% clay	x	o	o	o	x	x
< 5% clay	xx	o	o	xx	o	o
< 600 mm deep	xxx	x	x	x	x	x
600 - 1200 mm deep	xx	o	o	o	o	o
7. Initial infiltration rate of soil						
< 20 mm/h	x	xx	xx	x	xx	#
> 150 mm/h	xxx	o	o	o	o	o
8. Crops						
Nursery	xxx	x	o	o	xx	x
Row crops	x	o	xx	x	x	x
Bed crops	x	o	xx	xx	x	x
Field crops	o	o	xxx	xxx	o	o
Orchards, vineyards	x	x	o	x	xx	xx
Fungal diseases	o	xx	xx	o	xx	xx
Ablution of chemicals	o	xx	x	o	xx	xx
9. Operation						
Managerial inputs	xx	xx	xx	xxx	xx	x

Criteria	Flood	Sprinkler	Micro spray	Drip	Big gun / traveling irrigator	Centre pivot and linear move
Labour	xx	xx	o	o	x	o
Energy requirements	o	xx	xx	xx	xxx	xx
Water use	xxx	xx	xx	x	xx	xx
Application of chemicals	#	xx	x	x	xx	xxx

1.2 Allowable depletion levels of soil water

The following allowable depletion values are recommended to be used during the planning process to determine the size of the soil water reservoir and irrigation cycle length. These values are aimed at maintaining the maximum evapotranspiration rates of crops which were grouped according to water stress sensitivity (Annandale & Steyn, 2008).

Table 2 Allowable depletion values as a percentage of the available water in the active root zone

Crop group	Allowable depletion (% of available water) to maintain the following ET rates (mm/day)								
	2 mm	3mm	4 mm	5 mm	6 mm	7 mm	8 mm	9 mm	10 mm
1	50	43	35	30	25	23	20	20	18
2	68	58	48	40	35	33	28	25	23
3	80	70	60	50	45	43	38	35	30
4	88	80	70	60	55	50	45	43	40

Crop group 1: Onions, peppers, potatoes
Crop group 2: Bananas, cabbage, peas, tomatoes
Crop group 3: Lucern, beans, citrus, groundnuts, pineapples, sunflowers, watermelons, wheat
Crop group 4: Cotton, sorghum, olives, grapes, maize, soybeans, sugar beet, tobacco

Please note that the allowable water depletion (α) values provided above should be used in combination with the soil's total available water (the waterholding capacity (WHC) between -10 kPa and -1 500 kPa (WHC_{1500})).

Older methods used the water holding capacity (WHC) between -10 kPa and -100 kPa (WHC_{100}), for which different α values than those provided in Table 2 will be applicable. Care must be taken in using the relevant α and WHC values so that those used are applicable to the particular calculation.

1.3 Percentage wetted area

The values for the percentage of area that an irrigation system wets (W), that can be used during the planning process are displayed in Table 3. The values are based on data from FAO Publication nr 56 (Allen et al, 1998). In the case of drip irrigation, the lateral movement of water in the soil can be assessed with an on-site trial, and in the case of micro sprinklers, the wetted diameter of the specific sprinkler can be obtained from a manufacturer's catalogue to get a more accurate value.

Table 3 Percentage wetted area

Type of water application	W, %
Rain, Snow	100
Overhead Systems (Sprinklers, Centre Pivot, Linear, Traveling gun, Rotating boom) Drip	100
Micro sprinkler	30 – 40
Flood irrigation (basins and beds)	40 – 80
Flood irrigation (narrow furrows)	80 - 100
Flood irrigation (wide furrows)	60 – 100
Flood irrigation (alternative furrows)	40 – 60
	30 – 50

1.4 System Efficiency

Table 4 shows the recommended and minimum values for the efficiency of different types of irrigation systems based on the results of a WRC project (Reinders, 2010), and is determined by a water balance approach. The assumption is that the maximum theoretical efficiency of any irrigation system should be 100%. Assumptions are then made for acceptable losses in any system that can occur and the total losses deducted from 100%, to obtain the maximum (recommended) attainable efficiency. The minimum acceptable value is based on the previous norms. Although this process makes it possible for the designer to determine an appropriate efficiency for any specific situation that is being designed for, by putting together the loss percentage values, he/she must however always strive for a system designed for the maximum attainable efficiency.

The efficiency values shown in Table 4 apply only to the physical performance of the irrigation system and it is assumed that the irrigator applies appropriate and economical management practices.

Table 4 System efficiency

Irrigation system	Losses				Proposed default system efficiency (net to gross ratio) (%)	
	Non-beneficial spray evaporation and wind drift (%)	In-field conveyance losses (%)	Filter and minor losses (%)	Total Losses (%)	Min	Max
Drip (surface and subsurface)	0	0	5	5	90	95
Micro sprinkler	10	0	5	15	80	85
Centre Pivot, Linear move	8	0	2	10	80	90
Centre Pivot LEPA	0	0	5	5	85	95
Flood: Piped supply	0	0	2	5	80	95
Flood: Lined canal supplied	0	5	5	10	70	90
Flood: Earth canal supplied	0	12	5	14	60	86
Sprinkler (permanent)	8	0	2	10	75	90
Sprinkler (movable)	10	5	2	17	70	83
Traveling gun	15	5	2	22	65	78

1.5 Irrigation hours per week

These values are used to determine the required system discharge. The norms recommended by DWAF (1985) are accepted:

- Micro and permanent sprinkler systems ≤143 hours
- Centre pivots systems ≤143 hours
- Moveable sprinkler and other movable systems ≤108 hours
- Flood irrigation systems ≤60 hours

It is also highly recommended that the ESKOM tariff structure applicable to the irrigation system is taken into account when determining the number of hours available for irrigation per week.

1.6 Surveying and mapping

The map that will be used for the detailed design of the system should be drawn at an appropriate scale and contour interval, and it should be based on accurate data so that the irrigation system is designed correctly and all the design details can be legibly displayed.

1.6.1 Recommended contour intervals and scales of maps

The following scale and contour interval combinations are generally used:

Table 5 Recommended scales and contour intervals

Irrigation systems	Contour interval	Smallest scale
Micro irrigation (narrow row spacing: ≤ 3 m)	0,5 m	1: 500
Micro irrigation (wide row spacing: > 3 m)	1,0 m	1: 1 000
Sprinkler irrigation	1-2 m	1: 2 000
Centre pivots	2-5 m	1 : 5 000
Flood irrigation	0,5 m	1 : 1 000

1.6.2 Use of GPS Systems

Global Positioning Systems (GPS) surveying is an evolving technology. As GPS hardware and processing software are improved, new specifications will be developed and existing specifications will be changed.

GPS receivers can be divided into the following three categories:

a) Recreational Grade GPS / GNSS

Recreational grade GPS receivers are the least expensive and the simplest to use of the three types. These units have less functionality and are intended for recreational navigation uses. These units can be expected to produce locations with accuracy of approximately 15-30 meters. This grade of GPS is not advisable for data collection for irrigation design purposes.

b) Mapping/Resource Grade GPS / GNSS

Mapping or Resource Grade GPS collect positions with accuracies between 0.5 and 5 meters with differential corrections. These units have expanded functionality as well and can also record features as points, lines and polygons. These units also allow for loadable feature libraries designed to efficiently collect attribute information describing the feature.

c) Survey Grade GPS / GNSS

Survey grade GPS tools are intended for tasks requiring a very high degree of accuracy - positions determined by these receivers can be accurate to within less than a few centimeters. These systems produce data of the highest horizontal and vertical positional accuracy. They are relatively expensive and complex, requiring specialized training and dedicated staff to oversee its use.

The level of accuracy depends on the type of equipment you are using. In most cases for irrigation, the mapping (resource) grade receivers are adequate as some mapping grade receivers are even capable of sub-meter accuracy and better, especially when differential correction is applied, real-time or as post-processing.

The following guidelines for the selection of GPS equipment are proposed:

Table 6 Recommended GPS specifications

Minimum number of channels	250
Update rate	1 Hz
Correction	Global Real Time Differential Correction preferred
Accuracy	At a 95% confidence index:
Moving systems:	< 2.5 m
Sprinkler systems:	< 1 m
Micro and flood irrigation systems:	< 0.5 m
Antenna	External
Operating temperature	-20° C to + 60° C
Battery life	Minimum 5 hours (8 hours preferred)
Performance	Real Time Differential: 0.08m Horizontal, 0.16m Vertical RTK: 8mm + 1ppmHorizontal, 15mm + 1ppm Vertical
Protection	
Enclosure:	IP65 (dust proof and 1m water quick submersion)
Humidity:	100% sealed
Drop proof:	Shock proof against 1m drop
The following user settings are recommended:	
Minimum number of satellites	5
PDOP	< 3
Satellite filter angle	10°
Signal to noise ratio (SNR)	6
Other options recommended	Internal GSM for Network RTK (NTRIP) where available. Windows Mobile Data Logger with Survey/GIS software. Smart Voice Announcement System. System upgradeable to full RTK with base unit.

2. Irrigation systems

2.1 Micro sprinkler irrigation

2.1.1 Minimum gross application rate

The application rate should be equal to or greater than 3 mm/h on the wetted area (Lategan, 1995). Distribution tests can be done with the selected micro sprinkler on soils with poor water distribution ability, to ensure that dry patches will not occur in the wetting area of the sprayer.

2.1.2 Distribution Uniformity

a) Emitter uniformity approach

The following minimum emitter uniformity (EU) values are proposed:

- Level terrain where slope < 2%: EU = 95%
- Undulating terrain or slopes > 2%: EU = 90%

b) Conservative approach

The percentage emitter discharge variation should not exceed 10% of the design emitter discharge. In the case of emitters with a discharge exponent of 0.5, this will result in a maximum allowable pressure variation of 20% of the design pressure.

2.1.3 Flow velocity in laterals

A minimum flow velocity of 0,4 m/s at the lateral end point is required. (T-Tape, 1998)

2.2 Drip Irrigation

2.2.1 Distribution Uniformity

a) Emitter uniformity approach

The following emitter uniformity (EU) values are recommended for pressure sensitive drip emitters:

Table 7 Recommended EU Values of pressure sensitive drip irrigation systems

Emitter Type	Number of emitters per plant	Topography or slope	EU (%)	
			Min	Recommended
Point application	≥3	≤2%	90	95
Point application	<3	≤2%	85	90
Point application	≥3	Undulating terrain or slope >2%	85	90
Point application	<3	Undulating terrain or slope >2%	80	90
Line source	All	≤2%	80	90
Line source	All	Undulating terrain or slope >2%	80	85

If the EU value of 90% cannot be obtained with pressure sensitive emitters, it is strongly recommended that pressure compensating emitters should be used.

b) Conservative approach

The percentage emitter discharge variation should not exceed 10% of the design emitter discharge. In the case of pressure sensitive emitters with a discharge exponent of 0.5, this will result in a maximum allowable pressure variation of 20% of the design pressure.

c) Pressure compensating emitters

It is recommended that maximum allowable pressure variation (in m) will be within the following safety limits:

- Minimum design pressure = the minimum working pressure at which compensation takes place as per the manufacturer + 3m
- Maximum design pressure = the maximum working pressure at which compensation takes place as per the manufacturer – 5m.

Should the safety limits provided here result in a very narrow pressure band (for example in the case of thin-walled drip laterals with a relatively low maximum working pressure), the limits can be reduced after consulting with the manufacturer of the drippers.

2.2.2 Flow velocity in laterals required for effective flushing

The following minimum flow velocity at the lateral end point is required (Netafim, 2013):

- Good quality water: 0.4 m/s
- Average quality water: 0.5 m/s
- Poor quality water: 0.6 m/s

2.2.3 Flushing of laterals

If flushing manifolds are used, the pipe diameter of the laterals must be chosen correctly so that the friction losses do not exceed 0.5m over the length of the manifold (Netafim, 2008).

2.2.4 Flow velocity in manifolds

The maximum allowable flow velocity in any section of the manifold should be 2 m/s (Keller & Bliesner, 1990).

2.2.5 Specific management systems

There are several variations of the use of drip irrigation for which specialist knowledge and additional information can be obtained, for example:

- Underground drip irrigation. The publication on “Engineering aspects of sub-surface drip irrigation systems” (Koegelenberg, F. 2005. ARC- Institute for Agricultural Engineers) can be consulted.
- Open Hydroponics Systems and pulse irrigation. This system requires additional flow due to short irrigation times, and steps must be taken to keep water from draining from the system between irrigation start-ups. The Irrigation Design Manual of the ARC can be consulted for any queries.

2.3 Sprinkler Irrigation

2.3.1 Sprinkler selection

The operating pressure, sprinkler application, wetted diameter and spacing of the sprinklers all influence the performance of the specific sprinkler and nozzle combination. The Christiansen's uniformity coefficient (CU) is used to determine the water application in a laboratory. The sprinkler with the best CU value must be selected. The following norms for the selection of sprinklers based on the laboratory-tested CU values are recommended: (Keller, 1990):

- CU ≥ 85% for vegetable crops
- 75% ≤ CU ≤ 85% for deep rooted crops e.g. lucern
- CU ≥ 70% for tree crops

When applying chemicals through the system, the CU should be ≥ 80%.

2.3.2 Sprinkler spacing

The maximum sprinkler/lateral spacing is calculated as a percentage of the wetted diameter of the chosen sprinkler for the average wind speed as displayed in Table 8 (Rainbird, 1998):

Table 8 Sprinkler spacing according to average wind speed

Average Wind speed (km/h)	Maximum spacing between sprinkler/lateral in wind conditions displayed as a percentage of the wetted diameter of the chosen sprinkler.	
	Between sprinklers (%)	Between Laterals (%)
<10	40	65
10 - 15	40	60
>15	30	50

If the chosen sprinkler spacing surpasses the maximum allowable spacing for wind still conditions, then the spacing must be calculated according to the CU standards for wind still situations.

2.3.3 Minimum gross application rate

The following minimum gross application rates are recommended:

- Moveable systems ≥ 5 mm/h
- Permanent systems ≥ 4 mm/h

2.3.4 Maximum pressure variation

The diameter of a lateral should be designed so that the pressure variation between different sprinklers irrigating simultaneously is not more than 20% of the design pressure (Jensen 1983).

2.4 Centre Pivot

2.4.1 Maximum irrigation time vs. soil infiltration rate

The design of a centre pivot should ensure that the application rate does not exceed the soil's infiltration rate, especially at the end of the machine.

2.4.2 Christiansen uniformity coefficient (CU)

It is recommended that the CU as calculated by the supplier for the selected nozzle package should be ≥ 95%. In the field a 85% CU value can be expected.

2.4.3 Friction through centre pivot

≤ 3,6% (m/100m) of the total centre pivot length.

2.4.4 Effective radius of end gun

50% of the wetted radius of the end gun.

2.5 Travelling irrigators

2.5.1 Pressure variation over the length of the travelling path

The moving direction must be such that the pressure difference between the upper and lower ends of a strip does not exceed 20% of the working pressure.

2.5.2 Speed variation

The maximum speed variation allowed between the fastest and slowest speed is 10%.

2.5.3 Site

It is recommended that cross slopes over the strips be limited to less than 5% during system lay-out. A pressure regulator is recommended for travelling irrigators on steep slopes to ensure a constant flow rate.

2.5.4 Flow rate

The design flow rate must be increased by ± 2.5 m^3/h to allow for driving water when a hydraulically driven travelling irrigator is used. Confirmation of this value must be insured by the specific supplier.

2.5.5 Sprinkler choice

The type of sprinkler and pressure may be selected from the manufacturer's catalogue. Big gun sprinklers with a high jet angle (> 23 degrees) are only recommended for low wind areas. The following minimum working pressures are recommended to limit droplet size:

- 300 kPa for 12 mm nozzles
- 400 kPa for 14 mm and 16 mm nozzles
- 500 kPa for 18 mm and 20 mm nozzles

2.5.6 Strip width

Strips should be set out perpendicular to prevailing winds if possible. Manufacturer's manuals should be used in choosing strip widths. Because of the influence of wind on travelling irrigators, most manufacturers recommend strip widths for different wind velocities as follows:

Table 9 Reduction factors for travelling irrigator strip widths to allow for windy conditions

Wind velocity [km/h]	Strip width [% of wetted diameter]
0 - 8	70%
8 - 16	60%
> 16	50%

2.6 Flood irrigation

Although flood irrigation appears to be a relatively simple system, it requires various design information to ensure a well-designed scheme. The infiltration rate of the soil must be thoroughly investigated and the results thereof taken into account during the planning phase of the system. A water runoff control plan must be implemented to ensure that rainwater is kept away from the irrigation area.

The following norms are recommended:

2.6.1 Slope of beds

Slope along the length of the field must be < 0,7% to prevent erosion unless an in situ test is done. The slope across the width must be = 0% for basin and border irrigation.

2.6.2 Allowable flow depth in beds

50 mm $\leq$ flow depth $\leq$ 150 mm

2.6.3 Allowable soil infiltration rate per bed

It is recommended that the infiltration rate of the soil types occurring within one bed may not vary more than 10% from the average. Bed lay-out should be adjusted accordingly.

3. Water supply systems

3.1 Pipe friction in main- and sub main lines

The designer must take into account the possible effect of water quality on pipes as well as the deterioration of pipes with age during the pipe's life time. The following values for allowable pipe friction in mainlines are accepted as norms:

The following applies for pipelines with a diameter of 200 mm or smaller:

- Rising pipeline: Maximum friction loss = 1% (m/100m pipe length)
  Recommended friction loss = 0.6% (m/100m pipe length)
  Maximum velocity = 1.3 m/s
  Recommended velocity = 1 m/s
- Gravity pipeline: Maximum allowable flow velocity of 3.0 m/s

If the above figures are exceeded, then the designer must show that the chosen pipe diameter's total cost (capital and annual running cost) have been optimized and is the best of the available options.

For pipes with larger diameters, a full life cycle cost analysis (capital and annual running cost) is recommended to find the most economical pipe sizes.

For all pipes, and especially in the case of diameters larger than 200 mm, the effect of water hammer is critical and must be investigated and optimized. An adequate number of air valves must be included in the design.

3.2 Valves

The size of the valves at the inlet of the irrigation system must be chosen according to the manufacturer's recommendations for the specific application. In the absence of any recommendations, the valve must be chosen so that the pressure loss through the valve under normal operating conditions is less than 20 kPa.

3.3 Filters

The specification of filters is subject to any requirements stated by the manufacturer, for example the minimum pressure or flow rate required for the backwash of filters.

3.3.1 Disc and mesh filters

Disc / mesh filter openings must be ≤ 1/5 that of the emitter orifice diameter. The appropriate micro emitter manufacturer's recommendations must be used for flow path openings of ≤ 1mm. The following norms are accepted (ASAE EP405.1, 1997):

Table 10 Allowable pressure difference over a filter bank

Type	Allowable pressure difference over clean filter/-bank (kPa)		Allowable pressure build-up (kPa)	Allowable pressure difference before backwashing (kPa)	
	Single filter	Filter bank		Single filter	Filter bank
Disc-/Mesh filter	10	30	40	50	70

3.3.2 Sand Filters

When using a sand filter, a 200 μm control mesh or disc filter must be placed on the downstream side of the sand filter to catch the impurities in case of damage to the sand filter. The drip manufacturer's recommendations must be followed when using a disc- / mesh filter. The following norms are accepted.

a) Flow rate

The maximum allowable flow rate through a clean sand filter: Flow rate ≤ 50 m^3/h per m^2 of sand surface area with an allowable pressure difference over the clean sand filter of ≤ 10 kPa. A minimum of 50 % of the maximum filtration rate (50 m^3/h per m^2 sand surface area) is required to backwash the filters (Burt & Styles, 1994). The maximum backwash rate must not exceed 1,2 times the filtration rate.

b) Pressure difference

The allowable pressure difference over a sand filter with disc-/ mesh filters: Allowable pressure difference over a clean filter bank (including sand and disc filter) ≤ 40 kPa and over the filter bank before backwashing should be ≤ 60 kPa. When using a disc-/ mesh filter, the allowable pressure difference norms as described in section 3.3.1 must be complied with.

Table 11 Allowable pressure differences over sand filters

Type	Allowable pressure difference over clean filter/-bank (kPa)		Allowable pressure build-up (kPa)	Allowable pressure difference before backwashing (kPa)	
	Filter	Filter bank		Filter	Filter bank
Sand filter	10	40	20	30	60

c) Outlet pressure during backwash

Minimum pressure during backwash of a sand filter: ≥200 kPa (Smith, 2010)

d) Sand specifications used in sand filters

Silica sand with a particle size that varies from 0.6 to 1.4mm, with an acceptable sand grading, is recommended for sand filters. The recommended particle size grading must be 80 micron. A filtration performance of ≥90% must be achieved under laboratory conditions.

3.4 Design pump capacity (safety factor for wear and tear)

These values are added to the calculated system capacity and are used to determine the duty point (pressure and flow) when selecting a pump. The present norms are accepted:

- Discharge 10%
- Pressure head 5%

If fertilizers are pumped through the irrigation system then an additional 20% flow capacity can be designed for in the system.

3.5 Allowable velocity in the suction pipe

The standard for the maximum velocity in a suction pipe is 1.5 m/s, but the ideal velocity is between 0.75 m/s and 1 m/s. Turbulence will take place if the velocity is too high, which will ultimately cause cavitation in the system.

3.6 Pump efficiency

Although a fixed minimum value for efficiency of a pump cannot be given, the designer must always strive to choose the most efficient pump for the system.

It is recommended that a pump is selected for which the manufacturer can supply a test certificate, tested according to ISO 1940-1 Class 1 by the manufacturer.

It is furthermore recommended that the pump specified by the designer should meet the requirements of ISO 9906 Class A, which means that it should perform in practice within ±5% of the published pump curve (applicable to both centrifugal end-suction and borehole pumps).

3.7 Maximum motor power output

The correct selection of an electric motor will ensure that the motor is never overloaded. It is therefore necessary to either select a motor with a power rating that is large enough for the selected pump and impeller, or to make provision against overload by means of protection devices. Table 9 indicates norms for minimum power rating of an electric motor for specific output power if the motor is selected according to the normal duty point (output power required).

Table 12 Minimum power rating of electric motors for certain output powers

Output Power [kW]	≤ 7,5 kW	>7.5 kW
Minimum power rating of motor	Power requirement of the pump at the highest design duty point + 20% OR Maximum input power requirement of the pump as per the pump curve (overload point)	Power requirement of the pump at the highest design duty point. Overload protection essential

The reduction in the power rating of the motor, as set out in Table 17.4 and 17.5 of the Irrigation Design Manual of the ARC-IAE (2003 edition), must also be applied where necessary.

3.8 Motor efficiency

It is recommended that electric motors with an efficiency rating of at least "IE2" (or "EFF1") are used to drive the pump.

Efficiency	EFF system	IE systems
Premium		IE3
High	EFF1	IE2
Standard	EFF2	IE1
Lower than standard	EFF3	

3.9 Variable speed drives (VSDs)

The VSD's main function is the ability to vary the speed of the motor it is connected to. In the case of a centrifugal pump it is therefore possible with the VSD to use the same pump and impeller combination to supply water at various flow rates and pressure heads (duty points) without changing the impeller of the pump.

Greatest benefits of VSDs were shown for systems:

- where the duty points vary because of elevations differences between delivery points
- especially center pivots operating against slopes greater than 2% and static irrigation systems where block inlets are located at different elevations.

3.9.1 General

- The basic principles of correct pump and motor design and selection apply at all times.
- The integration of the VSD with the control system and automation of the irrigation system should be investigated in order to find the most appropriate and cost effective solution.
- Alternative options should be considered first, such as cutting the impeller to the correct size and using soft starters, especially in the case of single duty point applications, as they can offer more cost effective solutions than the installation of a VSD.
- The motor should be capable of delivering the required power of the pump at all the different duty points but should not be oversized.
- If no other information is available, it is recommended that the supply frequency to the motor should not be less than 25 Hz and not be more than 60 Hz.
- At very low frequencies, it may be necessary to install an auxiliary fan to the motor to ensure adequate cooling takes place.
- The motor with which the VSD is to be used, should be rated VSD compatible according to the manufacturer.
- The enclosure of the VSD to be used should have a suitable IP rating for the environment in which it is to be used (dust, moisture, etc.)
- When more than one VSD is used in parallel, or if more than one pump is used per VSD, the designer should make sure that the pumps will operate in all cases without influencing one another negatively from a hydraulic perspective.
- The integration of the VSD with the rest of the electrical system at the pump station must be assessed and if the situation requires it, the necessary electrical filters should be installed to protect all components of the system.
- Before a VSD is supplied, the designer should ensure that support or maintenance services for the VSD are readily available in the area.

3.9.2 Totally Enclosed Fan Cooled Motors (TEFC) Motors

- Where running speeds are expected to exceed the normal 50Hz frequency levels, contact the pump and motor manufacturers to find out if the proposed maximum running frequency of the motor is acceptable. Generally ≤ 60 Hz is accepted as the maximum but the manufacturer should confirm this.
- The motor maximum kW (power rating) must not be exceeded when pumping at any given time but in particular when running at higher than normal speed (> 50 Hz).
- It is generally advisable not to run the motor at a lower frequency than 25Hz for prolonged periods of time. If this is required, it is suggested that the motor manufacturer should be contacted to establish if the minimum running frequency of the motor can be decrease to below 25 Hz.

3.9.3 Submersible motors

- See first two points under TEFC.
- The minimum running frequency of a submersible motor will be determined by the minimum flow velocity across the motor, as stipulated by the motor manufacturer, as the flow also contributes to cooling of the motor.
- The necessary precautions need to be taken to prevent prolonged periods of no flow through the pump as it may lead to the damage of the motor.
- The maximum number of starts per day of the motor is as stated by the motor manufacturer.
- The maximum current demand of a submersible motor is usually greater than the current demand of a TEFC motor of similar power rating. The VSD must be able to meet both the current and the power requirements of the motor.

3.9.4 Electrical supply and connection

- The maximum allowable cable length between the motor and the VSD as recommended by the VSD manufacturer should be adhered to. This is of particular importance in the case of submersible motors. In general, it is recommended that all situations where the distance between the VSD and the motor is greater than 15 m, is investigated from a cable sizing perspective.
- The earthing of the VSD and motor must be in accordance to the requirements of the VSD manufacturer.
- If a VSD is used in conjunction with a generator, approval should be sought from both devices' manufacturers that the generator and the VSD can be used together.

4. Greenhouses and Tunnels

When an irrigation system is designed for greenhouses, it requires the precise application of water as a high value crop is irrigated in a relatively small volume of growing media. The media must be well drained and pulse irrigation should be possible. Each irrigation block must be provided with its own mainline. The system must be equipped with anti-drainage valves to ensure that the water does not drain out of the system when it is switched off. Because of this it is recommended that the pump house and valves are placed at the lowest point of the greenhouse. Provision should however be made for the system to be flushed. The following norms are recommended:

4.1 Crop water requirement (mm/day)

If a crop is grown in a soilless medium, there must be drainage due to leaching, for example if 33% of drainage water is required, then the application rate must be 50% more to the crops.

- Maximum daily demand (soilless medium in greenhouses):
  Design for 6 ℓ/m²/day for plant consumption plus 3 ℓ/m²/day (33% leaching) = 9 ℓ/m²/day. If more leaching is required, then the demand will increase.
- Maximum hourly demand (soilless medium in greenhouses):
  Design for 0.8 ℓ/m²/h for plant consumption plus 0.4 ℓ/m²/h (33% leaching) = 1.2 ℓ/m²/h. If more leaching is required, then the demand will increase.

In the case of tunnels, the maximum daily demand can be increased to 10 mm/day (excluding any leaching requirements).

4.2 Overhead irrigation

Christiansen uniformity coefficient (CU): ≥ 95%

Gross application rate (GAR): 12mm/h ≤ GAR ≤18mm/h

4.3 Drip Irrigation

- Drip Spacing:
  ≤ 0.3m (Soilless medium)
  ≤ 0.4m (Soil medium)

- Flush Velocity of laterals:
  ≥0.5 m/s is required at the end point of the lateral.

- Mainline velocity:
  ≤3.5 m/s (pipe diameter > 50mm)
  ≤3 m/s (pipe diameter ≤ 50mm)

4.4 Pipelines, Pumps and Accessories

- Friction losses through mainline:
  ≤ 1.5% (Maximum friction loss of longest section of the mainline)
  ≤ 2.2m/s (Maximum flow velocity in the rest of the mainlines)

Mainlines must be of such size that friction loss plus the static height combination for every mainline must be approximately the same.

- Velocity through filtration manifold:
  ≤3.2m/s

- Velocity through pump house mainline:
  ≤3 m/s

All mainline equipment and accessories (water meters, control valves and reflux valves) should be the same size as the mainlines.

- Allowable velocity through suction pipe:
  ≤1 m/s (when whole system is in use)

4.5 Installation of drainage pipes

The drain should be placed perpendicular to the direction dripper lines with a maximum drain interval according to the slope

- 1% slope, draining pipe interval ≤ 20 m.
- 1.5% slope, draining pipe interval ≤ 25 m.
- 2% slope, draining pipe interval ≤ 30 m.

NOTE: The slope of the drainage pipe should not exceed the slope of the site area.

4.6 Allowable ground slopes in greenhouses

- Parallel gutters (dripper pipe direction):
  Soilless medium: 1% <slope <2%
  Soil medium: 0.5% <slope <2%

- Perpendicular to gutters:
  Soil less medium: 0.25 % < slope < 2 %.
  Soil medium: 0.5 % <slope < 2 %.

NOTE: Confirm with Greenhouse Manufacturers.

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