B.C. SPRINKLER IRRIGATION MANUAL

Chapter 6

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Prepared and Web Published by

BRITISH COLUMBIA

Ministry of Agriculture

2014 ISSUE

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The primary purpose of this manual is to provide irrigation professionals and consultants with a methodology to properly design an agricultural irrigation system. This manual is also used as the reference material for the Irrigation Industry Association's agriculture sprinkler irrigation certification program.

While every effort has been made to ensure the accuracy and completeness of these materials, additional materials may be required to complete more advanced design for some systems. Advice of appropriate professionals and experts may assist in completing designs that are not adequately convered in this manual.

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GUN SYSTEM DESIGN

In irrigation, the term gun is used to describe high volume sprinklers with discharge rates exceeding 50 US gpm. This chapter will discuss both stationary and travelling guns. Flow rates for guns can vary from 50 to 1,000 US gpm. Gun operating pressures may range from 40 to 120 psi, depending on the gun and type of nozzle selected. For travelling guns, the pressure required at the cart will include the nozzle pressure and friction losses through the hose delivering water from the machine to the gun. Water is usually supplied to the gun by above ground aluminum pipes or buried PVC pipe with hydrants spaced to meet the designed gun spacing. Figure 6.1 shows an example of a travelling gun system.

Figure 6.1 Travelling Gun System

6.1 Nozzle Type

Guns come in a variety of sizes, trajectory angles, and available nozzles. The trajectory angle is important in determining maximum spray height and distance of throw. Gun systems can utilize three types of nozzles: taper bore, taper ring, and ring nozzles. Taper bore nozzles provide better stream integrity and create maximum distance of throw with less distortion due to wind. See Tables 6.8 – 6.12.

6.2 Operating Pressure

Due to the large discharge rates of gun systems, higher operating pressures than sprinkler system are required to ensure good stream break up. An increase in pressure at the gun nozzle increases stream velocity which breaks the water into finer droplets. A fast stream velocity also provides a larger wetted diameter which helps to reduce the instantaneous application rate of the gun system. Proper selection of a gun operating pressure must take into account the nozzle type, soil and crop conditions. In most instances, large droplets are to be avoided as they cause soil compaction and may also cause crop damage.

Gun systems are available in various trajectory angles. The higher trajectories maximize the wetted radius and allow for a near zero horizontal droplet velocity before reaching the crop. Lower trajectories operate more efficiently in windy conditions but do not have desirable droplet conditions. Lower trajectory guns need even higher operating pressures to ensure proper stream dispersal before contacting the crop. Table 6.1 indicates recommended minimum operating pressures for various gun sizes based on flow rate.

Table 6.1 Recommended Minimum Operating Pressures for Gun Systems

Flow Range [US gpm]	Minimum Pressure [psi]
100 – 200	65
200 – 300	70
300 – 400	80
400 – 500	85
500+	90

Special nozzle configurations have been developed to allow some gun systems to operate at pressures as low as 40 to 50 psi. Designers should check manufacturer's recommendations when using these low pressure gun systems.

Warning – Gun System Design

When operating gun systems near electrical transmission lines the operator must be very careful that the gun stream does not contact the power line. High voltage power lines can arc over to an irrigation stream if sufficient stream break up has not occurred. See Section 6.7 regarding minimum clearances between the jet stream and high voltage power lines.

Selecting a gun spacing, flow rate, nozzle size and operating pressure can be simplified using Tables 6.9, 6.10, 6.11 and 6.12. The designer must be conversant with application rates, spacing selection, crop and soil parameters and gun operation before using these tables. Both instantaneous and overlap application rates should be calculated.

6.3 Spacing Selection

Gun systems are spaced on the same design parameters as sprinkler irrigation systems, as explained in Section 3.2. However, extra caution should be taken with guns as they are subject to very poor distribution uniformities during windy conditions, due to the large wetted radius and height of throw. Instantaneous application rates also increase substantially when guns are operated during windy conditions. It is strongly recommended that gun systems not be operated during windy conditions. Table 6.2 provides a guide to gun spacing. Since gun systems are susceptible to wind drift, the maximum sprinkler spacing should not exceed 50% of the wetted diameter and the lateral spacing should not exceed 65% of the wetted diameter. Travelling guns can be spaced up to 65% of the wetted diameter in appropriate conditions.

Table 6.2 Gun Spacing Recommendations

Gun Type	Spacing as a Percentage of Wetted Diameter
Stationary Gun	Maximum sprinkler spacing = 50% Maximum lateral spacing = 65%
Travelling Gun	Maximum lane spacing = 65%

6.4 Application Rates

Gun systems should be operated differently from conventional sprinkler systems due to the inherent high application rates that are produced. Irrigation set times are therefore much shorter to apply the amount of water required by a crop. To reduce the rate at which water is applied to the soil, two guns should never be operated simultaneously side by side. Even so, it is difficult to design stationary gun systems so that the maximum application rate does not exceed the values stated in Table 4.4. Exceeding these values slightly may be acceptable if the set time is less than four hours. However, moving a gun system every three hours may not be practical. To match the gun operation with soil conditions the instantaneous application rate and the overlap application rate should both be calculated as described in the next sections 6.5 and 6.6.

6.5 Stationary Gun

Stationary guns are usually used in smaller odd-shaped fields, or to irrigate corners or areas not covered by the primary irrigation system such as a centre pivot or a wheelmove. They provide advantages in tall crop situations but the difficulty of moving them is also a limiting factor. Stationary guns have the lowest application efficiency (58% when the system is designed correctly) of all sprinkler system due to their inherent poor uniformity; however, they are still used because of their low capital cost and flexibility in irrigating odd-shaped areas. Stationary guns should not be used if the goal is improved irrigation performance and efficiency.

➔ **Typical Application Efficiencies of Sprinkler Irrigation Systems, Table 3.1**

Instantaneous Application Rate

Since two guns are not operating side by side at one time, the application rate formula that needs to be matched to the soil infiltration rate is different than it is for a sprinkler system.

The instantaneous application rate is the actual rate that water is applied to the soil surface by the stationary gun while it is operating. It takes into account the wetted diameter of the gun and the amount of water discharged by the gun. The instantaneous application rate is the value that is checked against the maximum soil infiltration rate values shown in Table 4.4 to minimize runoff from the soil surface.

For a stationary gun the Instantaneous Application Rate (IAR) can be calculated using equation 6.1:

Equation 6.1 Instantaneous Application Rate

$$IAR = \frac{Q \times 96.3}{\Pi \times R^2}$$

where

IAR = Instantaneous Application Rate [in/hr]
Q = Gun Flow Rate [US gpm]
Π = 3.14 (constant for an area of a circle)
R = Wetted Radius of the Gun [ft]

The instantaneous application rate may be increased significantly in windy conditions. The formula used above calculates the instantaneous application rate for perfect operating conditions.

Helpful Tips – Stationary Gun Operation

The maximum soil infiltration rates shown in Table 4.4 are based on irrigation system operation times exceeding 4 hours. The infiltration capacity of a soil will be higher than the values shown for application times less than 4 hours. To reduce runoff consider the following:

1. Monitor the soil while the gun is running to determine the maximum run time that can be achieved before signs of puddling and runoff occur.

2. Determine the MSWD of the crop and soil to ensure the gun application rate and run time does not exceed the soil storage capacity.

Overlap Application Rate

Stationary gun sets should be spaced according to the recommendations in Table 6.2 to give sufficient overlap for proper uniformity. Insufficient overlap will result in parts of the field being under-irrigated. The aerial photo in Figure 6.2 illustrates a poor overlap. No circles should be shown in the photo if the gun system had been set up with a spacing that provided a proper overlap.

➔ **Sprinkler Layout, Figure 5.1**

For a stationary gun, the overlap application rate (OAR) is used to determine the total amount of water applied to the soil after all of the irrigation sets have been completed (the entire field has been irrigated). It will be used to determine the maximum irrigation interval. The overlap application rate is calculated using the gun spacing and flow rate as shown in Equation 6.2:

Equation 6.2 Overlap Application Rate

$$OAR = \frac{Q \times 96.3}{S_1 \times S_2}$$

where

	OAR =	Overlap Application Rate [in/hr]
	Q =	Gun Flow Rate [US gpm]
	S_1 =	Gun Spacing along Lateral [ft]
	S_2 =	Lateral Spacing [ft]

Figure 6.2 Poor Overlap in Stationary Gun Operation

Application Efficiency

Stationary gun systems are less efficient than sprinkler systems due to higher operating pressures, susceptibility to wind drift and high application rates. The set times for gun systems are usually shorter than sprinkler systems to avoid over application and runoff. For design purposes, if guns are spaced at no more than 50% of the wetted diameter, application efficiencies of 58% to 60% are the best that can be achieved for these kinds of systems.

➔ **Typical Application Efficiencies of Sprinkler Irrigation Systems, Table 3.1**

Helpful Tips – Stationary Gun System Design

Stationary guns are often used in pastures where soils are compacted and the grass grown has a very shallow rooting depth. Take care to ensure that the MSWD is not exceeded. Most stationary gun systems should not run for more than four hours at one location. Automatic shutoffs should be incorporated where the system cannot be shutdown manually within this time frame.

Example 6.1 Stationary Gun in Merritt

Question: A farmer in Merritt intends to use a stationary gun to grow grass in a series of four pastures. The soil is a deep loam. The pasture area is made up of four 5 acre parcels that are 660 ft x 330 ft each. Total pasture area is 1320 ft x 660 ft. What nozzle, spacing, pressure should be selected and what is the set time and irrigation interval?

Information:

Farm location	*Merritt*	1	
Crop type	*Pasture*	2	
Soil texture	*Loam*	3	
Rooting depth (RD, Table 4.1)	*1.5*	4	ft
Available water soil capacity (AWSC, Table 4.2)	*2.0*	5	in/ft
Availability coefficient (AC, Table 4.3)	*0.50*	6	
Maximum application rate (Max. AR, Table 4.4)	*0.35*	7	in/hr
Peak Evapotranspiration (Peak ET, Table 4.5)	*0.28*	8	in/day
Estimated peak flow rate (Table 4.6)	*7.0*	9	US gpm
Irrigated acreage	*20*	10	acres
Application efficiency (AE, Table 3.1)	*0.58*	11	

Calculation:

Step 1. Determine the maximum soil water deficit (MSWD), maximum irrigation interval (Max. II), and system peak flow rate.

Equation 4.2

MSWD = RD x AWSC x AC

= *1.5* [4] ft x *2.0* [5] in/ft x *0.50* [6]

= *1.5* [12] in

Equation 4.3

$$\textbf{Max II} = \frac{\textbf{MSWD}}{\textbf{Peak ET}}$$

$$= \frac{1.5\ [12]\ \text{in}}{0.28\ [8]\ \text{in/day}}$$

= *5.5* [13] day

Equation 4.4

Peak Flow Rate = Estimated Peak Flow Rate Requirement per Acre x Irrigated Area

= *7.0* [9] US gpm x *20* [10] acres

= *140* [14] US gpm

Step 2. Select a gun nozzle, and determine gun set spacing.

Gun flow rate (Q, Table 6.9)	*136*	15	US gpm
Wetted diameter (Table 6.9)	*283*	16	ft
Nozzle type (Table 6.9)	*Taper bore*	17	
Nozzle size (Table 6.9)	*0.75*	18	in
Operating pressure (Table 6.9)	*70*	19	psi

Wetted Radius (R) = 50% of wetted diameter
= 50% x 283 **16** ft
= 142 **20** ft

Gun Spacing (S_1) = 50% of wetted diameter
= 50% x 283 **16** ft
= 142 ft
= 140 **21** ft (designer select)

Lateral Spacing (S_2) = 65% of wetted diameter
= 65% x 283 **16** ft
= 184 ft
= 180 **22** ft (designer select)

Step 3. Determine the set time.

Equation 6.1

$$\textbf{IAR} = \frac{Q \times 96.3}{\Pi \times R^2}$$

$$= \frac{136\ [15]\ \text{US gpm} \times 96.3}{\Pi \times (142\ [20]\ \text{ft})^2}$$

= 0.21 **23** in/hr must be less than Max AR of 0.35 **7** in/hr

Equation 6.2

$$\textbf{OAR} = \frac{Q \times 96.3}{S_1 \times S_2}$$

$$= \frac{136\ [15]\ \text{US gpm} \times 96.3}{140\ [21]\ \text{ft} \times 180\ [22]\ \text{ft}}$$

= 0.52 **24** in/hr

The system needs to be designed to match up with MSWD; therefore, NWR = MSWD.

Equation 5.3

$$\textbf{GWR} = \frac{NWR}{AE}$$

$$= \frac{MSWD}{AE}$$

$$= \frac{1.5\ [4]\ \text{in}}{0.58\ [11]}$$

= 2.6 **25** in

$$\textbf{Set Time} = \frac{GWR}{OAR}$$

$$= \frac{2.6\ [25]\ \text{in}}{0.52\ [24]\ \text{in/hr}}$$

= 5.0 **26** hr

Step 4. Determine the irrigation interval.

Grid Size = $S_1 \times S_2$

= *140* **21** ft x *180* **22** ft

Field Size = **Field Length x Field Width**

= *1,320* **27** ft x *660* **28** ft

# of Sets = $\dfrac{\textbf{Field Length}}{S_1} \times \dfrac{\textbf{Field Width}}{S_2}$

= $\dfrac{1{,}320 \;\textbf{27}\; \text{ft}}{140 \;\textbf{21}\; \text{ft}} \times \dfrac{660 \;\textbf{28}\; \text{ft}}{180 \;\textbf{22}\; \text{ft}}$

= *35* **29** sets

# of Sets per Day = $\dfrac{\textbf{24 hr}}{\textbf{Set time}}$

= $\dfrac{24\ \text{hr}}{5.0 \;\textbf{26}\; \text{hr}}$

= *4.8* **30** sets/day

Irrigation Interval = $\dfrac{\textbf{\# of Sets}}{\textbf{\# of Sets per Day}}$

= $\dfrac{35 \;\textbf{29}\; \text{sets}}{4 \;\textbf{30}\; \text{sets/day}}$

= *9* **31** day is over the Max. II of *5.5* **13** day

IMPORTANT:

This example shows the problems that are inherent with Stationary Guns. The poor efficiency, difficulty in matching gun spacing to fit the areas to be irrigated, and inability to move the system as often as required usually mean that the area is not irrigated as well as it should be. In this case, the irrigation interval is exceeded even if the system could be moved every five hours (set time) which is not practical and not likely.

6.6 Travelling Gun

Since travelling guns move during application, the application uniformity is much better than a stationary gun system. The efficiency of application may also be slightly higher as the potential for runoff is reduced. The maximum application efficiency for a travelling gun as shown in Table 3.1 is 65% for most B.C. conditions.

As indicated in Figure 6.3, travelling guns use a hose to drag the gun cart across the field. Hose and machine friction losses must therefore be taken into account when selecting machine connection pressure, ensuring that the nozzle operates above the minimum pressures required as shown in Table 6.1.

Travelling gun systems are susceptible to striking electrical transmission lines. The design standards shown in Section 6.7 should be followed when designing a system in the vicinity of high voltage power lines.

Travelling gun systems overcome the problem of the short set time generally required with stationary gun designs. The travelling gun system can irrigate larger parcels of land during one irrigation set. Flow rates generally range from a minimum of 50 US gpm up to 700 US gpm. For agricultural irrigation purposes in B.C., travelling gun systems in the 100 to 350 US gpm range are often used. Figure 6.3 shows how a travelling gun is operated to irrigate a field.

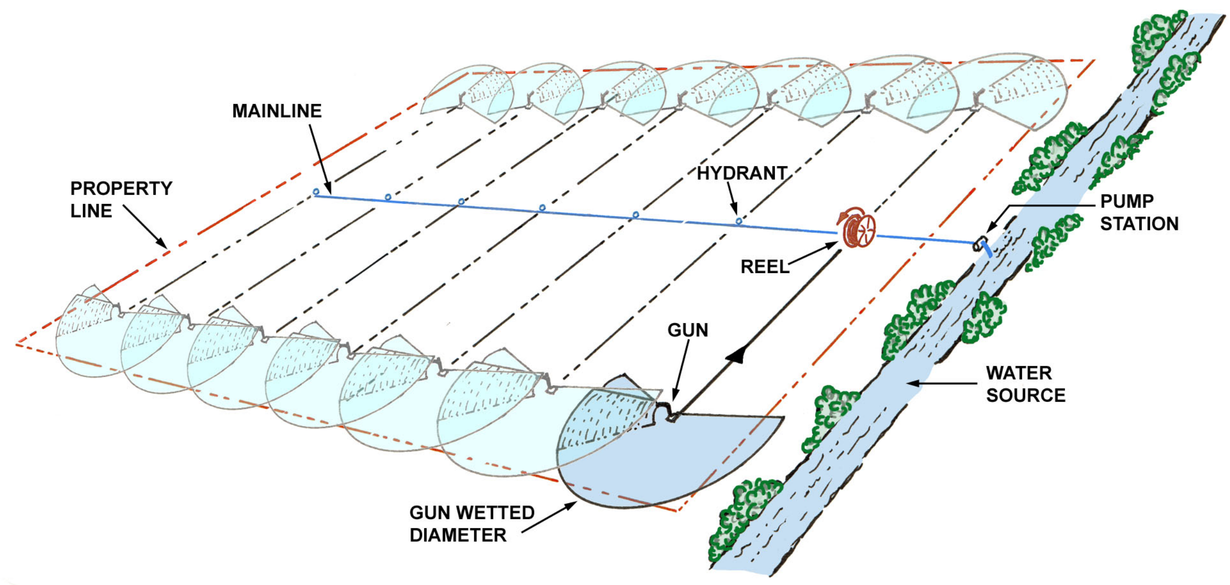


Figure 6.3 Hard Hose Reel Machine Layout

Travel Speed

The travel speed of a travelling gun can be adjusted to vary the amount of water applied. Adjustments to the travel speed can also be used to help reduce or eliminate puddling and runoff. Set times can be selected to suit the farm operation, however it is important that the irrigation system design and operation allows the machine to operate at least 23 hours per day to maximize efficiency of use. If total operating times are less than 23 hours per day then a peak flow rate per acre exceeding the values estimated in Table 4.6 may result.

The 23 hour set time is selected to allow time for moving the gun to the next set. The travel speed required is determined from Equation 6.3.

Equation 6.3 Travel Speed (T)

$$T = \frac{Field\ Length}{Set\ Time}$$

where

	T =	gun cart travel speed [ft/hr]
	Field length =	length of field [ft]
	Set time =	time to irrigate one set [hr]

Amount Applied per Irrigation

The amount applied by a travelling gun system is dependent upon the travel speed of the gun cart, the gun flow rate and gun spacing. The amount applied by the machine can be calculated by using Equation 6.4.

Equation 6.4 Gross Water Applied (GWA)

$$GWA = \frac{Q \times 96.3}{S \times T}$$

where

	GWA =	gross water applied during an irrigation interval [in]
	Q =	gun flow rate [US gpm]
	S =	lane spacing between sets [ft]
	T =	gun cart travel speed [ft/hr]

As a quick guide, Table 6.3 provides information on the GWA by a travelling gun for various flow rates, lane spacings and travel speeds.

The net water applied (NWA) is calculated by applying the application efficiency of the gun to the gross water applied (GWA). See Equation 6.5.

Equation 6.5 Net Water Applied (NWA)

$$NWA = GWA \times AE$$

where

	NWA =	net water applied during an irrigation interval [in]
	GWA =	gross water applied during an irrigation interval [in]
	AE =	application efficiency [% in decimal form]

Table 6.3 Depth of Water Applied by Travelling Guns (Inches)

Flow per Gun [US gpm]	Lane Spacing [ft]	Travel Speed [ft/hr]								
		20	30	40	60	80	100	120	150	180
100	120	4.01	2.68	2.00	1.33	1.00	0.80	0.67	0.54	0.43
	135	3.56	2.38	1.78	1.18	0.89	0.71	0.59	0.48	0.39
	150	3.21	2.14	1.60	1.07	0.80	0.64	0.54	0.43	0.36
150	135	5.35	3.57	2.68	1.78	1.34	1.07	0.89	0.71	0.59
	150	4.82	3.21	2.41	1.61	1.20	0.96	0.80	0.64	0.54
	165	4.37	2.92	2.19	1.46	1.09	0.88	0.73	0.58	0.49
	180	4.01	2.68	2.00	1.34	1.00	0.80	0.67	0.54	0.45
200	150	–	4.28	3.21	2.14	1.61	1.28	1.07	0.86	0.71
	165	5.83	3.89	2.92	1.95	1.46	1.17	0.97	0.78	0.65
	180	5.35	3.56	2.68	1.78	1.34	1.07	0.89	0.71	0.59
	200	4.81	3.21	2.40	1.60	1.20	0.96	0.80	0.64	0.54
250	160	–	5.01	3.76	2.50	1.38	1.50	1.25	1.00	0.84
	180	–	4.46	3.34	2.23	1.67	1.34	1.11	0.89	0.74
	200	–	4.00	3.00	2.00	1.50	1.20	1.00	0.80	0.67
	220	5.47	3.65	2.74	1.82	1.34	1.09	0.91	0.73	0.61
300	180	–	5.35	4.01	2.68	2.00	1.60	1.34	1.07	0.89
	200	–	4.81	3.61	2.40	1.81	1.44	1.20	0.96	0.80
	220	–	4.37	3.28	2.19	1.64	1.31	1.09	0.88	0.73
	240	–	4.00	3.00	2.00	1.50	1.20	1.00	0.80	0.67
350	180	–	–	4.68	3.12	2.34	1.87	1.56	1.25	1.04
	200	–	5.61	4.21	2.81	2.11	1.68	1.40	1.12	0.94
	220	–	5.11	3.83	2.55	1.92	1.53	1.28	1.02	0.85
	240	–	4.68	3.51	2.34	1.76	1.40	1.17	0.94	0.78
400	200	–	–	4.81	3.21	2.41	1.92	1.60	1.28	1.07
	220	–	5.84	4.37	2.92	2.19	1.75	1.46	1.17	0.97
	240	–	5.35	4.01	2.68	2.00	1.60	1.34	1.07	0.89
	260	–	4.94	3.70	2.47	1.85	1.48	1.23	0.99	0.82
450	200	5.42	4.33	3.61	2.71	2.17	1.81	1.55	1.35	1.20
	220	4.92	3.94	3.28	2.46	1.97	1.64	1.41	1.23	1.09
	240	4.51	3.61	3.00	2.26	1.81	1.50	1.29	1.13	1.00
	260	4.17	3.33	2.78	2.08	1.67	1.39	1.19	1.04	0.93
500	220	5.47	4.38	3.64	2.74	2.18	1.82	1.56	1.37	1.22
	240	5.01	4.01	3.34	2.51	2.00	1.67	1.43	1.25	1.11
	260	4.62	3.70	3.09	2.31	1.85	1.54	1.32	1.16	1.03
	280	4.30	3.44	2.87	2.15	1.71	1.43	1.23	1.07	0.95
550	220	6.01	4.81	4.01	3.00	2.40	2.00	1.71	1.50	1.34
	240	5.51	4.41	3.67	2.76	2.20	1.84	1.58	1.38	1.23
	260	5.09	4.07	3.40	2.55	2.04	1.70	1.46	1.27	1.13
	280	4.73	3.78	3.15	2.36	1.89	1.58	1.35	1.18	1.05
600	240	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	260	5.55	4.44	3.70	2.78	2.22	1.85	1.59	1.39	1.23
	280	5.15	4.13	3.44	2.58	2.06	1.72	1.47	1.29	1.15
	300	4.81	3.85	3.21	2.41	1.92	1.60	1.38	1.20	1.07
650	240	–	5.21	4.35	3.26	2.60	2.17	1.86	1.63	1.45
	260	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	280	5.59	4.47	3.73	2.79	2.24	1.86	1.60	1.40	1.24
	300	5.22	4.17	3.48	2.61	2.09	1.74	1.49	1.30	1.16
700	260	–	5.19	4.32	3.24	2.59	2.16	1.85	1.62	1.44
	280	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	300	5.62	4.49	3.75	2.81	2.24	1.87	1.61	1.40	1.25
	320	5.27	4.21	3.51	2.63	2.10	1.75	1.50	1.32	1.17

Note: The blanks indicate depths of application exceeding 6 inches, which will exceed the MSWD for most plant and soil combinations; therefore, are not recommended.

Instantaneous Application Rate

Part circle guns are used on travelling gun systems to ensure that the cart is pulled along dry ground, ahead of the area being irrigated. This also ensures that the gun does not irrigate beyond the field boundary when the gun cart approaches the machine. The instantaneous application rate (IAR) of the gun will be affected by the part circle. For a proper design, the IAR must not exceed the maximum application rate for the type of soil texture and field type. The part circle of the gun should be maximized while still allow the cart to be dragged through the non-irrigated area. Equation 6.6 illustrates how to determine the instantaneous application rate for part circle guns.

Equation 6.6 Instantaneous Application Rate (IAR)

$$IAR = \frac{Q \times 96.3}{\prod \times R^2 \times c}$$

where

IAR = Instantaneous application rate [in/hr]
Q = gun flow rate [US gpm]
R = wetted radius of the gun [ft]
c = percentage of full circle covered by gun [% in decimal form]

Table 6.4 can be used as a guide to determine the instantaneous application rate of a travelling gun. The application rates shown are theoretical values that can be obtained in perfect operating conditions. Windy conditions may substantially affect the application rates shown. The gun radius values indicated are average values taken from manufacturer's specifications.

Helpful Tips – Travelling Gun System Design

Travelling gun machines are often designed to swivel the machine 180^{o} so that the gun cart can be pulled out in both directions without having to move the machine. If the field is large enough then consider putting the mainline down the middle to utilize this option. It will reduce moving set up time. The travel speed selected should ensure that the soil and crop MSWD is not exceeded.

Note that in Table 6.4 the IAR of the gun is reduced as the arc of the gun is increased. Designers should consider increasing the arc if possible where the IAR of the gun is exceeding the maximum soil infiltration rate.

Table 6.4 Instantaneous Application Rates for Part Circle Guns

Gun Flow Rate [US gpm]	Gun Radius [ft]	Instantaneous Application Rate [in/hr]	
		180° arc (c = 0.5)	240° arc (c = 0.67)
100	130	0.36	0.27
150	150	0.41	0.31
200	160	0.48	0.36
250	175	0.50	0.37
300	185	0.54	0.40
350	190	0.59	0.44
400	200	0.61	0.46
450	210	0.63	0.47
500	215	0.66	0.49
550	220	0.70	0.52
600	225	0.73	0.54
650	230	0.75	0.56
700	235	0.78	0.58

Helpful Tips – Travelling Gun System Design Example 6.2

In example 6.2, note that the MSWD for the crop and soil is 3.0 inches and the maximum irrigation interval is 14 days if the soil is filled up entirely to the MSWD. However, for the travelling gun system, since the net amount of water applied is 1 inch, the actual irrigation interval during peak conditions is 5.5 days. This indicates that slower travel speeds could be used to increase the amount of water applied and lengthening the actual irrigation interval. No more than 3.0 inches could be applied at one time however or the MSWD would be exceeded.

Helpful Tips – Irrigation Design Parameters

The travelling gun irrigation design plan shown here is also provided in Appendix C with the corresponding design parameters shown on the adjacent page. The design parameter summary is useful for evaluating the irrigation system design and performance characteristics. This information should be included with every irrigation system plan.

Example 6.2 Travelling Gun in Armstrong

Question: The farmer in Armstrong (examples 4.1, 4.3 and 4.5) wants to use a travelling gun to irrigate three 40-acre (1,320 ft x 1,320 ft) alfalfa fields consisting of deep sandy loam soil. What nozzle, pressure and lane spacing will be required per travelling gun? What would will be the net water applied per irrigation?

Information:

Farm location	*Armstrong*	**1**	
Crop type	*Alfalfa*	**2**	
Soil texture	*SL*	**3**	
Maximum soil water deficit (MSWD, Box 8, Example 4.1)	*3.0*	**4**	in
Maximum irrigation interval (Max. II, Box 8, Example 4.3)	*14*	**5**	days
Maximum application rate (Max. AR, Table 4.4)	*0.45*	**6**	in/hr
Peak Evapotranspiration (Peak ET, Table 4.5)	*0.21*	**7**	in/day
Estimated peak flow rate (Table 4.6)	*5.25*	**8**	US gpm
Irrigated area per field	*40*	**9**	acres
Field length	*1,320*	**10**	ft
Application efficiency (AE, Table 3.1)	*0.65*	**11**	

The set time for a travelling gun is generally 23.5 hours with 0.5 hour for moving the gun to the next set.

Set time = *23.5* **12** hr

Calculation:

Step 1. Determine the system peak flow rate.

Equation 4.4

Peak Flow Rate = Estimated Peak Flow Rate Requirement per Acre x Irrigated Area

= *5.25* **8** US gpm x *40* **9** acres

= *210* **13** US gpm

Step 2. Select a gun nozzle, and determine gun set spacing.

Gun flow rate (Q, Table 6.10)	*210*	**14**	US gpm
Wetted diameter (Table 6.10)	*335*	**15**	ft
Nozzle type (Table 6.10)	*Taper bore*	**16**	
Nozzle size (Table 6.10)	*0.9*	**17**	in
Nozzle pressure (Table 6.10)	*80*	**18**	psi
c value	*0.67*	**19**	

Wetted Radius (R) = 50% of wetted diameter

= 50% x *335* **14** ft

= *168* **20** ft

Maximum Lane Spacing = 60% of wetted diameter

= 60% x *335* **14** ft

= *201* **21** ft

A round number will be easier to work with in the field. For convenience, set

Lane Spacing = *200* **22** ft

Step 3. Check the Instantaneous Application Rate (IAR).

From Table 6.4, IAR = 0.48 in/hr for a 180° arc, and IAR = 0.36 in/hr for a 240° arc. The maximum application rate cannot be exceeded. Therefore, the gun should be operated with at least a 240° arc in this case.

Gun trajectory | 240° | 23 |

Equation 6.6

$$IAR = \frac{Q \times 96.3}{\Pi \times R^2 \times c}$$

$$= \frac{\boxed{210}\ \boxed{14}\ \text{US gpm} \times 96.3}{\Pi \times (\ \boxed{168}\ \boxed{20}\ \text{ft})^2 \times \boxed{0.67}\ \boxed{19}}$$

= | 0.34 | 24 | in/hr which must be less than Max AR of | 0.45 | 6 | in/hr

Step 4. Determine the travel speed (T), gross water applied (GWA), and net water applied (NWA).

Equation 6.3

$$T = \frac{\text{Field Length}}{\text{Set Time}}$$

$$= \frac{\boxed{1,320}\ \boxed{10}\ \text{ft}}{\boxed{23.5}\ \boxed{12}\ \text{hr}}$$

= | 56 | 25 | ft/hr

Equation 6.4

$$GWA = \frac{Q \times 96.3}{S \times T}$$

$$= \frac{\boxed{210}\ \boxed{14}\ \text{US gpm} \times 96.3}{\boxed{200}\ \boxed{22}\ \text{ft} \times \boxed{56}\ \boxed{25}\ \text{ft/hr}}$$

= | 1.8 | 26 | in

Equation 6.5

NWA = GWA x AE

= | 1.8 | 26 | in x | 0.65 | 11 |

= | 1.17 | 27 | in

Equation 5.2

$$II = \frac{NWA}{ET}$$

$$= \frac{\boxed{1.17}\ \boxed{27}\ \text{in}}{\boxed{0.21}\ \boxed{7}\ \text{in/d}}$$

= | 5.6 | 28 | days which is less than Max II of | 14 | 5 | day

Note:

With a spacing of 200 feet the unit will take 6.5 days to cover the field. In hot weather the crop water demand may be greater than the irrigation systems ability to supply water. If the travelling gun application rate exceeds the soil capability, even at arcs approaching full circle, the gun travel speed should be increased to shorten the duration of application as much as possible.

Figure 6.4

TRAVELLING GUN

SAMPLE SPRINKLER IRRIGATION PLAN

GENERAL FARM INFORMATION

• CROP	ALFALFA
• IRRIGATED AREAS (acres)	120
• IRRIGATION INTERVAL (days)	6.5
• No. OF IRRIGATIONS SETS PER UNIT	6.5

PUMP SPECIFICATIONS

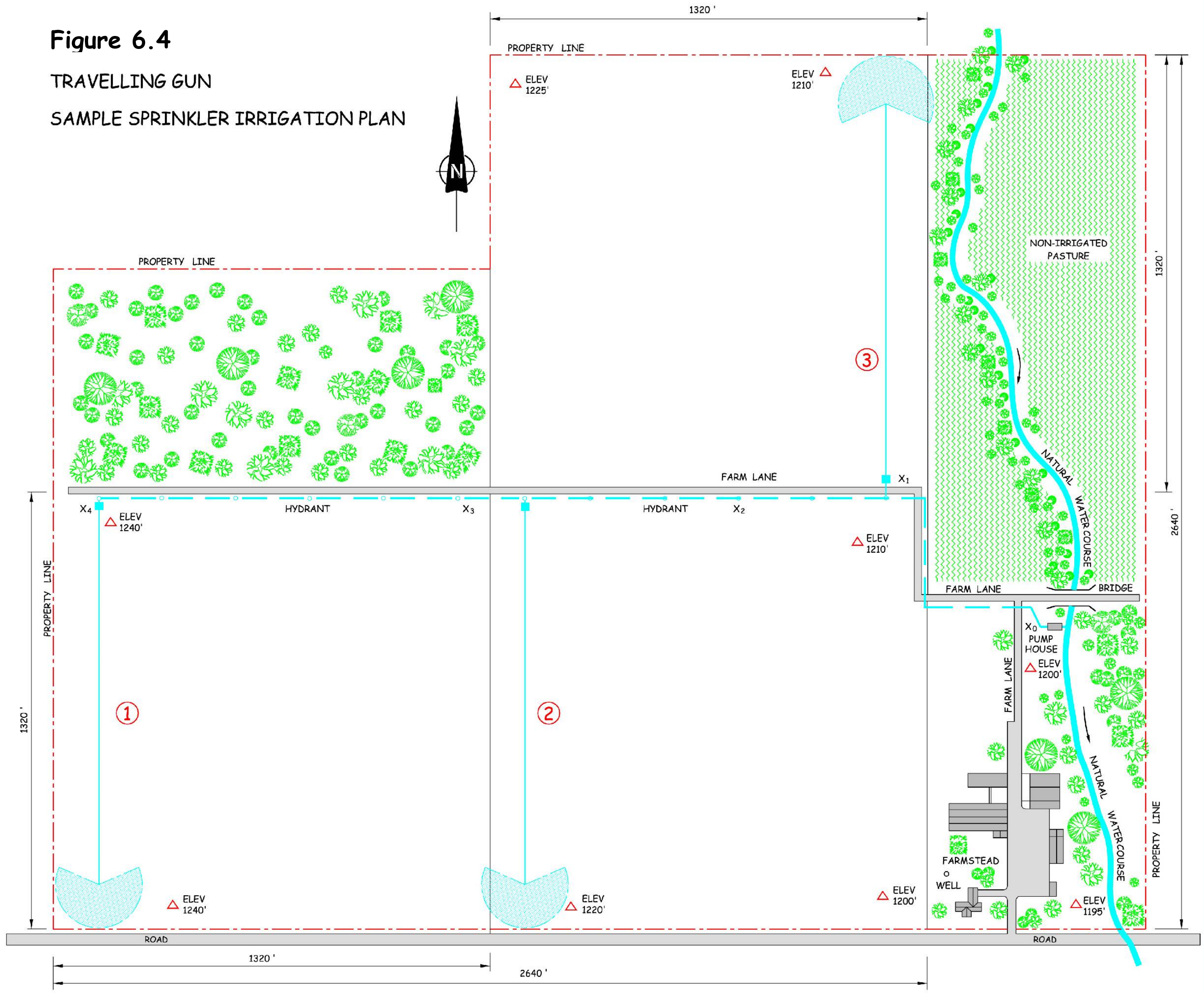
• HORSEPOWER (hp)	75
• FLOW RATE (US gpm)	630
• TOTAL DYNAMIC HEAD	344

NOZZLE SPECIFICATIONS

	for 1, 2, and 3
• NOZZLE SIZE (inches)	0.9 TAPER BORE
• NOZZLE OPERATING PRESSURE (psi)	80
• NOZZLE FLOW RATE (US gpm)	210
TOTAL No. OF NOZZLES	3
TOAL FLOW RATE (USgpm)	630

LEGEND

- PROPERTY LINE
- ELEVATION
- TREES AND BUSH
- ROAD AND FARM LANE
- BUILDINGS
- MAINLINE with HYDRANTS
- TRAVELLING GUN
- TRAVELLING GUN NUMBER



6.7 System Design Consideration near Electrical Transmission Lines

Striking electrical transmission lines with an irrigation water jet can cause current transfers that may be dangerous to an operator touching the machine. Current transfers can occur in the following conditions:

- Direct contact of the irrigation system with the transmission line.
- Leakage current – the result of an alternative path being provided for the conduction of electrical current. This situation can arise when concentrated jets of water from the irrigation system come into contact with transmission line conductors. (Current flows from the power line to the nozzle through the water jet).
- Flashovers – occur when the insulating qualities of the air are not great enough to overcome the potential difference between a conductor and objects at another potential. Flashovers can occur between conductor to tower, phase to phase and conductor to ground due to a water jet interacting with the power line.

An irrigation water jet striking a transmission line is also a nuisance to the power utility because:

- The force exerted on the lines by the water jet can be many times the weight load or expected wind loading. Swaying of the conductors can result.
- A flashover can create power outages which may interrupt service to thousands of customers.

Minimum Clearance Standards

To ensure safe operation of irrigation equipment near transmission lines, minimum separation distances are required from the gun to the transmission lines. The clearance required between the water jet and the live conductors is a function of the voltage of the conductor. The values shown in Table 6.5 are the minimum acceptable clearances provided by BC Hydro for various line voltages.

The total water spray height includes the working height of the nozzle plus the maximum stream height above the nozzle. Two irrigation system types that have working heights which interact with power lines are centre pivots and gun systems. Working heights of centre pivot systems range from 12 to 25 feet (3.6 to 7.6 metres); however, most pivots are less than 14 feet (4.2 metres) in height. The working height of a travelling gun ranges from 6 to 11 feet (1.8 to 3.3 metres). These heights are required to permit these systems to operate over crops such as corn, providing good uniformity without damaging the crop.

Table 6.5 Irrigation Water Jet to Power Line Clearance Standards				
Line Voltage [kV]	**Phase Spacing (S) [ft]**	**Min. Mid-Span Height (H) [ft]**	**Conductor-to-Water Clearance (Y) [ft]**	**Allowable Stream Spray Height (L) [ft]**
69	5.0	18.0	2.0	16.0
138	14.0	22.6	3.0	19.6
230	18.0	24.3	5.0	19.3
387	22.0	25.6	6.2	19.4
345	34.8	28.5	7.5	21.0
500	45.0	32.8	10.5	22.3
Source: BC Hydro				

Calculating Maximum Stream Height

While the working height of a nozzle can be measured easily, the maximum stream height is more difficult. The maximum stream height is a function of the type of sprinkler, angle of trajectory, nozzle size and operating pressure.

Manufacturers indicate maximum stream heights for various impact sprinklers but not for giant guns.

Nelson Irrigation Corporation has developed a formula for determining the maximum stream height and location of maximum stream height for gun systems based on the wetted diameter and pressure (assuming that the gun is operating on level ground).

Equation 6.7 Stream Height

(a) $$X = 0.3 \times D$$

(b) $$Z = C \times D - K \times D^2$$

where
- X = Horizontal distance from the nozzle at which maximum stream height occurs (ft)
- Z = Maximum stream height above sprinkler nozzle (ft)
- D = Wetted diameter (ft)
- C = Dimensionless factor dependent on barrel trajectory
- K = Dimensionless factor dependent on barrel trajectory and operating pressure

Figure 6.4 shows the various parameters used in Equation 6.7. The dimensionless factors “C” and “K” can be determined from Table 6.6 and Table 6.7.

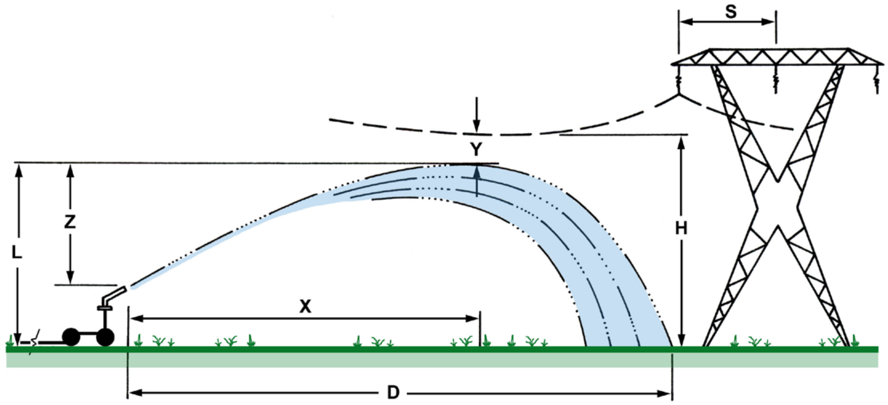


Figure 6.5 Schematic Indicating Gun Spray Trajectories

Table 6.6 C Values

Trajectory	15°	18°	21°	24°	27°
C Value	0.067	0.081	0.096	0.111	0.127

Source: Nelson Irrigation Corporation

Table 6.7 K Values

	Trajectory				
PSI	**15°**	**18°**	**21°**	**24°**	**27°**
40	0.181×10^{-3}	0.187×10^{-3}	0.194×10^{-3}	0.203×10^{-3}	0.213×10^{-3}
68	0.121×10^{-3}	0.125×10^{-3}	0.129×10^{-3}	0.135×10^{-3}	0.142×10^{-3}
80	0.091×10^{-3}	0.093×10^{-3}	0.097×10^{-3}	0.101×10^{-3}	0.107×10^{-3}
100	0.072×10^{-3}	0.075×10^{-3}	0.078×10^{-3}	0.081×10^{-3}	0.085×10^{-3}

Source: Nelson Irrigation Corporation

Helpful Tips – Distance from Electrical Transmission Line

The maximum stream height and the distance this height occurs from the nozzle are useful when designing systems that are close to transmission lines. However as demonstrated in Example 6.3, the distance the gun cart must be kept from a transmission line is difficult to determine as there is no calculation for determining how fast the stream height diminishes after the maximum height is reached.

Field observation should also be used in addition to the calculations. The transmission line height will be the lowest on the hottest day of the year. The minimum setback distance will be the required clearance distance plus the distance from the cart that the maximum stream height occurs. Actual distance should probably be further at a point where good stream breakup has occurred. The field should be staked at the point where the gun should be towed to.

Example 6.3 Maximum Stream Height

Question: What is the maximum stream height of the gun system selected in example 6.2 if the cart height is 7 ft? The nozzle selected was a 0.9-inch taper bore nozzle operating at 80 psi with a 24° trajectory. The flow rate is 210 US gpm with a wetted diameter of 335 ft.

What is the distance that the gun cart should be kept from a 500 kV transmission line?

Information:

Flow rate	210	1	US gpm
Wetted diameter (D)	335	2	ft
C value (Table 6.6)	0.111	3	
Cart height	7	4	ft

Select a K value for the pressure that is closest to 80 psi:

K value (Table 6.7)	0.101×10^{-3}	5

Calculation:

Equation 6.3 (a)

X = 0.3 x D

= 0.3 x 335 [2] ft

= 100 [6] ft

Equation 6.3 (b)

Z = C x D – K x D²

= 0.111 [3] x 335 [2] ft – 0.101×10^{-3} [5] x (335 [2] ft) ²

= 25.9 [7] ft

Total Height = Cart Height + Z

= 7 [4] ft + 25.9 [7] ft

= 32.9 [8] ft

Answer:

A maximum stream height of 25.9 ft occurs 100 ft from the gun operating a 0.9 inch taper bore nozzle at 80 psi with a 24° trajectory. Adding the cart height of 7 ft means the total height is 32.9 ft.

From Table 6.5, the mid-span height (H) of a 500kV transmission line is 32.8 ft, approximately the same height of the gun stream. The conductor to water clearance (Y) is a minimum of 10.5 ft. Visual observation will be required to determine where a safe distance for the gun cart to start irrigating will be. The minimum distance will be 110.5 ft away from the transmission line. (100 + 10.5).

Table 6.8 provides close approximations for stream heights and the distance the height occurs from the nozzle for various nozzles, pressures, flow rates and nozzle trajectories. Equations 6.7 (a) and 6.7 (b) were used to determine these values. The nozzle height from the ground must be added to these values to get the overall height.

Comparing values in Table 6.8 with clearance requirements in Table 6.5, only the smaller nozzles with lower trajectories have stream heights that may go under the larger transmission lines.

Table 6.8 Stream Trajectory Data for Giant Guns with Taper Bore Nozzles

Nozzle	Pressure [psi]	Flow Rate [US gpm]	Nozzle Trajectory [°]	Wetted Diameter (D) [ft]	Radial Distance to Maximum Stream Height (x) [ft]	Maximum Stream Height (Z) [ft]
0.6″	60	81	18	229	69	12.0
			21	233	70	15.4
			24	240	72	18.9
	80	94	18	251	75	14.5
			21	253	76	18.1
			24	260	78	22.0
0.7″	60	110	18	252	76	12.5
			21	257	77	16.1
			24	265	80	19.9
	80	128	18	278	83	15.3
			21	281	84	19.3
			24	290	87	23.7
0.8″	60	143	18	272	82	12.8
			21	276	83	16.7
			24	285	86	20.7
	80	165	18	302	91	16.0
			21	304	91	20.2
			24	310	93	24.7
0.9″	60	182	18	287	86	13.0
			21	296	89	17.1
			24	305	92	21.3
	80	210	18	323	97	16.5
			21	328	98	21.0
			24	335	101	25.9
1.0″	60	225	21	315	95	17.4
			24	325	98	21.8
	80	260	21	344	103	21.5
			24	355	107	26.7
	100	290	21	364	109	24.6
			24	375	113	30.2
1.1″	80	330	21	375	113	22.4
			24	387	116	27.8
			27	395	119	33.5
	100	370	21	400	120	25.9
			24	412	124	32.0
			27	420	126	38.3
1.3″	80	445	21	409	123	23.0
			24	421	126	28.8
			27	430	129	34.8
	100	500	21	437	131	27.1
			24	451	135	33.6
			27	460	138	40.4
1.6″	80	675	21	470	141	23.7
			24	475	143	29.9
			27	485	146	36.4
	100	755	21	494	148	28.4
			24	510	153	35.5
			27	520	156	43.1

Values are approximations only.

Table 6.9 Gun Nozzle Performance - Series 75 Guns 24^{o} Trajectory

TAPER RING NOZZLES

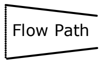
	0.5″		0.55″		0.6″		0.65″		0.7″		0.75″		0.8″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
35	40	164′	49	172′	59	178′	69	191′	81	196′	93	202′		
40	43	171′	52	180′	63	190′	74	198′	87	204′	98	213′	112	221′
45	46	180′	56	189′	67	198′	79	206′	91	214′	104	223′	118	230′
50	48	186′	59	195′	70	203′	83	212′	95	220′	109	230′	123	237′
55	50	193′	62	203′	74	213′	87	221′	100	230′	115	239′	130	247′
60	53	198′	64	208′	77	220′	91	228′	104	237′	120	245′	136	254′
65	55	205′	67	216′	80	227′	95	237′	109	247′	125	254′	142	263′
70	57	210′	69	221′	83	232′	98	243′	113	254′	129	260′	147	270′
75	59	217′	72	228′	86	239′	101	250′	117	261′	134	268′	153	277′
80	61	222′	74	234′	89	244′	105	256′	121	266′	138	274′	158	283′

The diameter of flow is approximately 3% less for the 21^{o} trajectory angle, and 6% less for 18^{o}.

Source: Nelson Irrigation Corporation

Table 6.10 Gun Nozzle Performance – Series 100 Guns 24° Trajectory

TAPER BORE NOZZLES

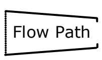


	0.50″		0.55″		0.60″		0.65″		0.70″		0.75″		0.80″		0.85″		0.90″		1.0″	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
40	47	191′	57	202′	66	213′	78	222′	91	230′	103	240′	118	250′	134	256′	152	262′		
50	50	205′	64	215′	74	225′	87	235′	100	245′	115	256′	130	265′	150	273′	165	280′	204	300′
60	55	215′	69	227′	81	240′	96	250′	110	260′	126	270′	143	280′	164	288′	182	295′	224	316′
70	60	225′	75	238′	88	250′	103	263′	120	275′	136	283′	155	295′	177	302′	197	310′	243	338′
80	64	235′	79	248′	94	260′	110	273′	128	285′	146	295′	165	305′	189	314′	210	325′	258	354′
90	68	245′	83	258′	100	270′	117	283′	135	295′	155	306′	175	315′	201	326′	223	335′	274	362′
100	72	255′	87	268′	106	280′	123	293′	143	305′	163	316′	185	325′	212	336′	235	345′	289	372′
110	76	265′	92	278′	111	290′	129	303′	150	315′	171	324′	195	335′	222	344′	247	355′	304	380′

TAPER RING NOZZLES

	0.64″		0.68″		0.72″		0.76″		0.80″		0.84″		0.88″		0.92″		0.96″	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
40	67	212′	76	219′	86	225′	98	233′	110	242′	125	250′	136	254′	151	259′	166	275′
50	75	224′	85	231′	97	240′	110	250′	123	258′	139	266′	152	271′	169	279′	185	288′
60	83	239′	94	246′	106	254′	120	264′	135	273′	153	281′	167	286′	186	294′	203	303′
70	89	249′	101	259′	114	268′	130	277′	146	286′	165	295′	180	300′	200	309′	219	320′
80	95	259′	108	269′	122	278′	139	288′	156	297′	176	306′	193	313′	214	324′	235	336′
90	101	268′	115	278′	130	289′	147	299′	166	308′	187	317′	204	324′	227	334′	249	345′
100	107	278′	121	288′	137	298′	155	308′	175	318′	197	327′	216	334′	240	344′	262	355′
110	112	288′	127	298′	143	308′	163	317′	183	326′	207	336′	226	342′	251	353′	275	364′

RING NOZZLES

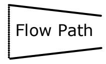


	0.71″		0.77″		0.81″		0.86″		0.89″		0.93″		0.96″	
PSI	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA	GPM	DIA
40	66	208′	78	212′	91	215′	103	224′	118	235′	134	238′	152	242′
50	74	220′	88	225′	100	230′	115	240′	129	250′	150	255′	167	260′
60	81	235′	96	240′	110	245′	125	260′	141	270′	164	275′	183	280′
70	88	245′	104	250′	118	260′	135	275′	152	290′	177	295′	198	300′
80	94	255′	111	265′	127	275′	145	285′	163	300′	189	305′	211	315′
90	99	265′	117	275′	134	285′	154	295′	173	310′	201	315′	224	325′
100	105	270′	124	280′	142	295′	162	305′	182	320′	212	325′	236	335′
110	110	275′	130	290′	149	305′	170	315′	191	325′	222	335′	248	345′

The diameter of flow is approximately 3% less for the 21° trajectory angle, and 6% less for 18°. ***Source:*** Nelson Irrigation Corporation

Table 6.11 Gun Nozzle Performance - Series 150 Guns 24^{o} Trajectory

TAPER BORE NOZZLES

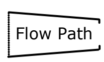


	0.70″		0.80″		0.90″		1.0″		1.1″		1.2″		1.3″		1.4″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
50	100	250′	130	270′	165	290′	205	310′	255	330′	300	345′	350	360′	408	373′
60	110	265′	143	285′	182	305′	225	325′	275	345′	330	365′	385	380′	446	396′
70	120	280′	155	300′	197	320′	245	340′	295	360′	355	380′	415	395′	483	412′
80	128	290′	165	310′	210	335′	260	355′	315	375′	380	395′	445	410′	516	427′
90	135	300′	175	320′	223	345′	275	365′	335	390′	405	410′	475	425′	547	442′
100	143	310′	185	330′	235	355′	290	375′	355	400′	425	420′	500	440′	577	458′
110	150	320′	195	340′	247	365′	305	385′	370	410′	445	430′	525	450′	605	471′
120	157	330′	204	350′	258	375′	320	395′	385	420′	465	440′	545	460′	632	481′

TAPER RING NOZZLES

	0.88″		0.96″		1.04″		1.12″		1.2″		1.28″		1.36″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
50	135	270′	164	286′	196	302′	233	318′	274	333′	319	347′	369	358′
60	148	284′	179	301′	214	317′	255	334′	301	351′	350	367′	405	378′
70	159	299′	194	315′	231	331′	276	349′	325	366′	378	382′	437	393′
80	170	310′	207	330′	247	346′	295	364′	347	381′	404	397′	467	409′
90	181	320′	220	340′	262	357′	313	377′	368	396′	429	411′	495	424′
100	191	329′	231	350′	277	366′	330	386′	388	405′	452	423′	522	436′
110	200	339′	243	359′	290	376′	346	397′	407	416′	474	433′	548	446′
120	209	349′	253	369′	303	386′	361	407′	425	426′	495	443′	572	457′

RING NOZZLES

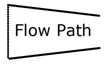


	0.86″		0.97″		1.08″		1.18″		1.26″		1.34″		1.41″		1.47″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
50	100	245′	130	265′	165	285′	205	300′	255	320′	300	335′	350	350′	385	353′
60	110	260′	143	280′	182	300′	225	315′	275	335′	330	350′	385	365′	423	368′
70	120	270′	155	290′	197	310′	245	330′	295	350′	355	365′	415	380′	458	383′
80	128	280′	165	300′	210	320′	260	340′	315	360′	380	380′	445	395′	490	399′
90	135	290′	175	310′	223	330′	275	350′	335	370′	405	390′	475	405′	522	409′
100	143	300′	185	320′	235	340′	290	360′	355	380′	425	400′	500	415′	550	419′
110	150	310′	195	330′	247	350′	305	370′	370	390′	445	410′	525	425′	577	429′
120	157	315′	204	335′	258	360′	320	380′	385	400′	465	420′	545	435′	603	439′

The diameter of throw is approximately 3% less for the 21^{o} trajectory angle. ***Source:*** Nelson Irrigation Corporation

Table 6.12 Gun Nozzle Performance – Series 200 Guns 27° Trajectory

TAPER BORE NOZZLES



	1.05″		1.1″		1.2″		1.3″		1.4″		1.5″		1.6″		1.75″		1.9″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
60	250	345′	285	355′	330	375′	385	390′	445	410′	515	430′	585	445′	695	470′	825	495′
70	270	360′	310	380′	355	395′	415	410′	480	430′	555	450′	630	465′	755	495′	890	515′
80	290	375′	330	395′	380	410′	445	430′	515	450′	590	470′	675	485′	805	515′	950	535′
90	310	390′	350	410′	405	425′	475	445′	545	465′	625	485′	715	505′	855	535′	1005	555′
100	325	400′	370	420′	425	440′	500	460′	575	480′	660	500′	755	520′	900	550′	1060	575′
110	340	410′	390	430′	445	450′	525	470′	605	495′	695	515′	790	535′	945	565′	1110	590′
120	355	420′	405	440′	465	460′	545	480′	630	505′	725	530′	825	550′	985	580′	1160	605′
130	370	425′	425	445′	485	465′	565	485′	655	515′	755	540′	860	560′	1025	590′	1210	620′

RING NOZZLES

	1.29″		1.46″		1.56″		1.66″		1.74″		1.83″		1.93″	
PSI	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**	**GPM**	**DIA**
50	230	325′	300	355′	350	370′	410	390′	470	405′	535	420′	640	435′
60	250	340′	330	370′	385	390′	445	410′	515	425′	585	440′	695	455′
70	270	355′	355	385′	415	405′	480	425′	555	440′	630	455′	755	475′
80	290	370′	380	400′	445	420′	515	440′	590	455′	675	470′	805	490′
90	310	380′	405	415′	475	435′	545	455′	625	470′	715	485′	855	505′
100	325	390′	425	425′	500	445′	575	465′	660	480′	755	500′	900	520′
110	340	400′	445	435′	525	455′	605	475′	695	490′	790	510′	945	535′
120	355	410′	465	445′	545	465′	630	485′	725	500′	825	520′	985	545′
130	370	415′	485	450′	565	470′	655	490′	755	505′	860	525′	1025	550′

The diameter of flow is approximately 2% less for the 24° trajectory angle, and 5% less for 21°. ***Source:*** Nelson Irrigation Corporation