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## ABC's of Sprinkler Irrigation

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*ABC's* OF *Sprinkler*  
**IRRIGATION**

AGRICULTURAL ENGINEERING DEPARTMENT  
AGRICULTURAL EXPERIMENT STATION  
SOUTH DAKOTA STATE COLLEGE  
B R O O K I N G S ,   S O U T H   D A K O T A

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# ABC's of Sprinkler Irrigation

By J. L. WIERSMA<sup>1</sup>

Many farm operators wish to reduce weather risks in the production of high-income farm products, realizing, even in comparatively wet years, the detrimental effects of short drought periods during the growing season.

A number of farmers in all sections of South Dakota have limited water supplies from which they could irrigate part of their land. Quite often, sprinkler irrigation will fit into their farm management program to a greater advantage than surface irrigation. In the first place, suitable areas for surface irrigation are scattered, and land preparation equipment and operators skilled for land leveling work are not available. Secondly, the skill required to irrigate with sprinklers is often much less than that needed with surface methods.

A dry-land farmer can learn in progressive stages the science of irrigation farming if the system is properly designed and a knowledge of the plant and soil is available. Also, in nearly all instances, only part of the farm is irrigated, with the remainder of the farm operated as it has been in the past. In such instances the time schedule works out to a better advantage with sprinklers than with surface methods of

irrigation. Lastly, better utilization of limited water supplies is possible with sprinklers.

All sprinkler irrigation systems will not be successful. In some cases, surface methods would be more successful, and in some, the land should not be irrigated, regardless of the method used.

Those planning to irrigate should first investigate the quantity and quality of water to be used and examine the soil as to suitability for irrigation.

The right to use water for irrigation purposes is of great importance. Regardless of the source of water supply, it is necessary to obtain a water right or permit.

## The Water

Several factors affecting the quality and quantity of the water supply have to be determined before a sprinkler system is installed.

**Quality of Water.** All waters carry varying quantities of certain chemicals that are referred to as dissolved salts. If their concentration is not too great, some of the constituents of these dissolved salts improve the growth of plants. More often, other

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salts are present which are harmful to plant growth and to soils. The total concentration of dissolved salts is expressed in the unit of parts per million (ppm), most irrigation water being in the range of 100 to 1,500 ppm.

The more important elements that form these dissolved salts are calcium, magnesium and sodium. Because calcium, magnesium and sodium salts have varying effects on plant growth and soils, the percent of each in the water supply must be known. Therefore, an analysis which gives only the total ppm of salts is not sufficient for a determination as to its suitability for irrigation purposes. When analysis is made, it should be for the express purpose of determining its suitability as irrigation water. South Dakota State College offers this service to farmers for a nominal charge. Water samples should be sent to the Agricultural Engineering Department, Brookings, South Dakota. An analysis will be made of the water and an explanation given as to its suitability.

As a detailed analysis of water is time-consuming, care should be taken that the sample is representative of the water supply from which it is taken. Samples from streams should be drawn from running water well downstream from any tributaries. Those from wells should be taken after the well has been in operation for some time. Samples from dams should be taken from the deep water area. Clean glass bottles with rubber stoppers are suitable containers in which to send samples

for analysis. These should be sent to the laboratory promptly after collection. A record of information should accompany the sample, giving the source and location of the water supply.

The analysis will vary somewhat during the year. For example, when the water supply is low a higher percentage of soluble salts will be found in the water.

**Quantity of Water Needed.** The total quantity of water and the rate at which it is available will govern both the number of acres of land that can be irrigated with the water supply and the required number of hours operation of the equipment to apply a given amount.

If the water supply is a surface reservoir, the rate of availability is determined by the size of pumping unit that is used and the total quantity of water available depends on storage area in the reservoir. On the other hand, a well or stream will yield water at a fixed rate and the total quantity of water will depend upon the total number of hours of pumping time at that particular rate. At least 1½-acre feet of water should be available for each acre of land that is to be irrigated.

Table 1 gives the number of gallons of water per minute per acre inch of water applied that will be needed to irrigate a given tract of land. For instance, to irrigate 60 acres of land every 22 days by operating the equipment 12 hours a day would require a water supply of 150 gallons per minute (gpm) (60 x 2.5) per inch depth of water stored in the soil. If the land requires an

Table 1. Number of Gallons Needed per Minute per Acre Inch of Water Stored in the Soil\*

Interval Between Irrigations Days	Hours Operation per Day				
	10	10	12	16	20
	Gallons per Min.	Gallons per Min.	Gallons per Min.	Gallons per Min.	Gallons per Min.
10 .....	8.1	6.5	5.4	4.1	3.3
15 .....	5.4	4.3	3.6	2.7	2.2
18 .....	4.5	3.6	3.0	1.6	2.3
22 .....	3.7	3.0	2.5	1.9	1.5
30 .....	2.7	2.2	1.8	1.4	1.1

\*Based on an assumed efficiency of 70%.

application of 3 inches of water every 22 days it would take 450 gpm (150 x 3) of water per minute. On the other hand, if the equipment were operated 20 hours a day it would require 90 gpm (60 x 1.5) per inch, or 270 gpm for a 3-inch application. This is based on an expected irrigation efficiency of 70 percent.<sup>2</sup>

### Soil

Planning for a successful sprinkler system depends upon a thorough knowledge of the plant, soil, and water relationships. Before doing any extensive planning as to the type of sprinkler equipment to be used, a soil survey of the area to be irrigated should be completed.

All soils are not irrigable. Soil, just as water, may contain soluble salts that are detrimental to plant growth under sustained irrigation. Nearly all South Dakota lands that have good surface and subsurface drainage will be relatively free from these harmful salts and will respond to irrigation water.

The ideal soil for irrigation is a deep fertile loam or fine sandy loam with excellent surface and subsurface drainage. These soils are advantageous because of their high

water-holding capacity; they permit a relatively rapid rate of water application which will bring fertility to a high level. Naturally, any textures from the loam can be irrigated successfully, but usually at a greater cost and with more labor.

Fertility of irrigated soils is of great importance for several reasons: farming under irrigation is relatively expensive and high yields are necessary for profitable results; under good irrigation practices, water is no longer the limiting factor of production and crops can respond to a high level of fertility with correspondingly good yields; also, there is less water used per unit of crop produced for fertile, than for infertile soil.

So far as the topographic features of the land are concerned, any land that can be farmed successfully can be sprinkler irrigated.

The amount of water that should be applied and the rate of application for an irrigation depend strictly upon soil texture and the type of profile. Table 2 can be used for general guidance in determining the amount and rate of application. This table is only approximate and as-

<sup>2</sup>Irrigation efficiency is here defined as the ratio of the water pumped into the system to the water stored in the root zone of the soil.

Table 2. Moisture Holding Capacity and Maximum Application Rates

Soil Type	Water to Replenish Soil Moisture for Following Soil Depth*			Maximum Rate of Water Application on Land With Slopes Less Than 5%
	2 Ft.	4 Ft.	6 Ft.	In. per Hr.
	Sand .....	1.9	3.0	3.8
Sandy loam .....	2.1	3.1	3.9	1.8
Fine sandy loam .....	2.1	3.1	3.9	1.3
Loam .....	2.2	3.4	4.3	1.0
Silt loam .....	2.4	3.6	4.5	0.7
Clay loam .....	2.7	3.9	4.9	0.5
Clay .....	3.1	4.3	5.0	0.4
Heavy clay .....	3.3	4.5	5.0	0.2

\*This is based on irrigating when 60% of the moisture available to the plant has been used by the plant and based on 100% irrigation efficiency. Many irrigators will begin irrigating when 50% of the available moisture has been used. To correct for this difference multiply the above figure by 0.80.

sumes a uniform soil throughout the profile. (Very few soil profiles will be uniform throughout.) Also, it is based on a water application efficiency of 100 percent which is never attained. The estimated efficiencies should be divided into the figure found in the table to determine the total amount of water to apply.

To use Table 2, the peak moisture requirement of the crop grown must be estimated. Sprinkler irrigation systems are designed for the peak requirement of the crop that is the heaviest water user. Thus, most systems are designed for a crop which will use a maximum of 0.25 inch of water per day.

By using Table 2, the frequency of irrigation and the rate of water application can be determined. A typical example: A loam soil with a profile 4 feet deep, below which is incoherent sand, is used to grow alfalfa (0.25 inch of water will be used per day). Table 2 shows that a loam 4 feet deep will hold 3.4 inches of available water for the alfalfa, or the soil will hold enough water to supply the alfalfa for 13.5 days ( $3.4 \div 0.25$ ). A sprinkler system must be

sufficiently large under these conditions to cover the irrigated land once every 13 days. The maximum rate of application is 1 inch per hour.

Natural rainfall was purposely omitted in this example because past experience has shown that 13-day drought periods are not uncommon. Therefore, the natural rainfall will not alter the size system that must be installed, but it will affect the total hours of operation during each season.

## Equipment

The equipment used in a sprinkler system is made up of five definite parts: the pumping unit, main line pipe, lateral line pipe, sprinkler heads, and fittings. The type and size of equipment must be suitable for the particular installation for which it is designed if it is to be successful.

**The Pump and Power Unit.** The pump and the power unit must be carefully selected in order to obtain economy in pumping operations.

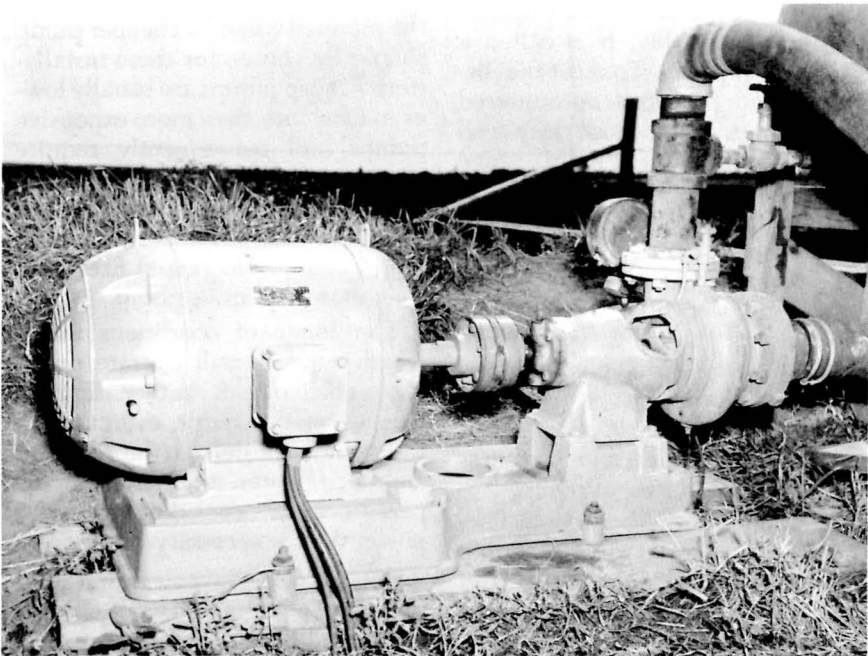
The deep-well turbine and the horizontal centrifugal pumps are the two most common types of pumps used. (Fig. 1).

**Centrifugal Pumps.** Horizontal centrifugal pumps are limited in use by the amount of suction lift present. This lift should not exceed 15 feet. Because this is the cheaper type pump, it will be used wherever it is possible. In order to keep the suction lift within its limits, pump pits have been constructed; their use, however, is limited, due to the fact that they are difficult to keep water-tight and to service.

Inasmuch as centrifugal pumps are non-positive in their operation, they have to be primed; that is, the pump casing and suction pipe must

be completely filled with liquid before the pump will operate. It is important that it remain primed while running, since the bearings usually require water for lubrication and cooling purposes. If the pump should lose its prime, and it is not shut down, severe damage will result. To protect against this happening, a device can be installed that will automatically shut off the engine or motor. This device can also be made to shut an engine off in case of overheating or a drop in oil pressure.

The size of the centrifugal pump is commonly designated by the discharge at a given pressure. The size of intake and discharge opening is not a correct indication as to pump



**Figure 1.** An electrically driven centrifugal pump. The suction lift with this type pump should not exceed 15 feet for economical operation.



capacity. The intake is usually larger than the discharge opening, inasmuch as friction loss in the suction line is part of the maximum practical suction lift, and the larger the pipe the less the friction loss will be.

**Deep - Well Turbine Pump.** Pumps that are suspended by the discharge column with the drive shaft enclosed are referred to as deep-well turbines. This type pump must be used when the suction lift exceeds the distance considered practical for a centrifugal pump. The turbine pumps use the same principle as a centrifugal pump, with the impeller operating below the water surface. Because the impeller is below water surface, the pump does not need to be primed.

If the pump contains one impeller and bowl assembly, it is called a single stage pump. To meet the discharge and pressures encountered in irrigation work, most deep-well turbine pumps are multi-stage pumps with a series of impellers. In this case, one is placed on top of another.

Performance curves for turbine pumps and centrifugal pumps are similar since they both operate under the same principle. Turbine pumps, however, cannot operate at as high an efficiency over so great a range of discharges and pressures as a straight centrifugal pump.

In locations where seasonal fluctuations in the water table are apt to occur, a variable speed power unit must be used if a constant discharge is required throughout the season. Such a unit will be necessary because the discharge will vary with

the height the water has to be lifted.

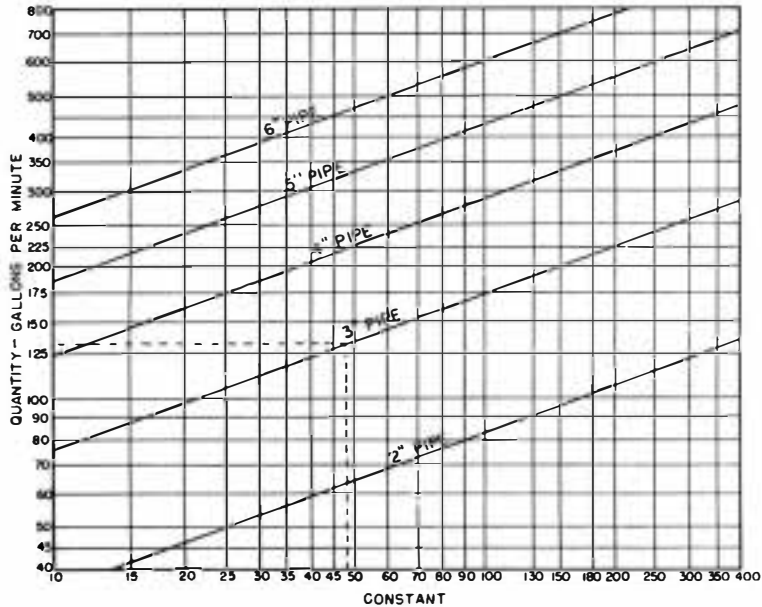
**Selecting a Pump.** In selecting an irrigation pump, the choice is nearly always between the centrifugal or a deep-well turbine pump. Deep-well turbines are used in practically all well installations except those where the water is very near the surface. Centrifugal pumps are more satisfactory for pumping from reservoirs, canals and streams.

The initial investment that can be made in a pump will depend upon the value of the crop grown and upon the total number of hours that the pump will be used per season. If the pumping hours are few, an expensive unit generally will not be economical, due to the high fixed cost that must be charged against the pumped water. A cheaper pump should be chosen for these installations. Cheap pumps are usually lower in efficiency than more expensive pumps and consequently require more power. If the pump will be used for a great number of hours per year the added power cost will more than offset the increased fixed cost for a more expensive pump.

The range of conditions under which a pump will operate under high efficiency is rather limited. Outside of this range, even though the pump will deliver the required amount of water, it does so at an expenditure of considerably more power than is necessary.

**Power Unit.** The power unit used to drive the pump will vary with the local conditions. Electric power requires the least attendance, and is the most trouble-free. Gasoline and

FIGURE 2  
LATERAL LINE FRICTION LOSS



Based on sprinklers 40 feet apart on lateral.  
For spacing other than 40 feet multiply friction loss for 40 feet by Spacing / 40

Sample Calculations

Lateral made up of one size pipe

Given: 11 sprinklers spaced 40' apart discharging 12 gpm on 3" lateral.

Find friction loss:  
Total discharge - 132 gpm.

Draw line from 132 gpm on left hand scale until it intersects diagonal line for 3" pipe.

Draw line from point of intersection to base line reading Constant 48.5

Friction loss is equal to Constant divided by discharge per sprinkler

Friction loss -  $48.5 / 12 = 4.4$  Pounds  
If spacing between sprinklers is 30'  
Friction loss -  $30 / 40$  of  $4.4 = 3.3$  pounds per square inch

Lateral made up of two sizes of pipe

Given: 33 sprinklers 20' apart, 16 of which are on 4" and 17 on 3" pipe  
Find friction loss if each sprinkler is discharging 10 gpm.

Discharge - 170 gpm through 3" and 160 gpm through 4" pipe. Total - 330 gpm

Find friction loss in 3" pipe for 170 gpm as in example of left -  $95 / 10 = 9.5$  psi  
4" section has 330 gallons entering and 170 gallons flowing into 3" section. Draw line from 330 gpm on left hand scale to diagonal line for 4" pipe and read 145 on base line

Draw line from 170 gpm to diagonal for 4" pipe and read 24 on base line. Subtract -  $145 - 24 = 121$   
Friction loss in 4" pipe -  $121 / 10 = 12.1$  psi  
Friction loss in 3" & 4" -  $9.5 + 12.1 = 21.6$  psi for 40' spacing  
Friction loss for 20' spacing -  $20 / 40$  of  $21.6 = 10.8$  pounds per square inch

propane engines are used most frequently in South Dakota. Diesel power is justified on large installations where the pumping time is great. Some pumps are powered by a farm tractor. Many farmers have a second tractor used for heavy work that is idle during the irrigation season. This makes an excellent power source if it is the size required for the pump.

**Main Line and Lateral Pipe.** The main line pipe and lateral pipe used to convey water to the sprinkler heads can be made of aluminum, galvanized steel, asphalt dipped steel, or it can be a composition pipe. Aluminum pipe has the least weight per unit size and is, therefore, used on the portable portion of any installation.

The portable lines are equipped with a quick coupler which is positive in action and very easily and quickly detached and attached. The tubing comes in 10-, 20-, 30-, and 40-foot lengths. Until recently 20-foot lengths were standard, but now many 30-foot and 40-foot lengths have come into use on pipe sizes less than 4 inches in diameter.

When selecting the diameter of pipe to be used on an installation, the friction loss that will develop by carrying the necessary water must be kept in mind. A size must be chosen that will keep the friction loss to a minimum and still be comparatively reasonable in price. Figures 2 and 3 give an approximation of the friction losses that will be encountered under various conditions. The maximum friction loss in lateral lines should not exceed 20 percent

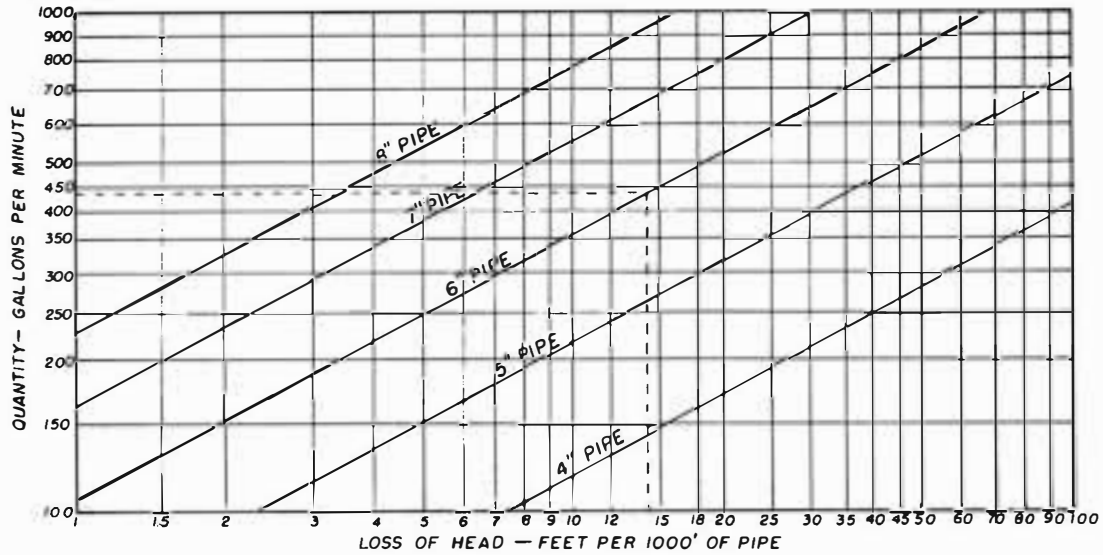
of the average operating pressure of the sprinkler heads used. A 20 percent pressure difference in a lateral line will result in approximately a 10 percent variance in water application.

One of the most important specifications for an irrigation system layout is to provide laterals which will not exceed 20 percent pressure variation. This would include any friction loss in the lateral line pipe, in addition to the loss or gain which would be obtained from difference in elevation in the ends of the lateral line.

The maximum main line friction losses permissible will depend largely upon the cost of pumping. The annual cost of the main line should be reasonably in balance with the cost of pumping water through them each year. If the number of pumping hours per year is small, a smaller main, in which there is greater friction loss and a resultant higher pumping cost per hour, would be permissible. However, if the system is in operation continuously, a larger and more costly main would be justified.

**Sprinkler Heads.** The sprinklers used in all systems are slow revolving sprinklers in which a jet of water is used to rotate the head between one and five revolutions per minute. The capacities and the operating pressures of various heads have a wide range. The commonly used heads vary in capacity from 5 to 30 gallons discharge per minute per sprinkler. The operating pressures vary from 10 pounds per square inch to 50 pounds per square inch.

FIGURE 3  
 MAIN LINE FRICTION LOSS (AL. PIPE)



**Sample Calculation**

Given: 6" pipe, Q - 440 gallons per minute

Find friction loss for main 800 feet long

Draw line from 440 g.p.m. on left hand scale until it

intersects diagonal line for 6" pipe

Draw line from point of intersection to base line

Reading - 14.5' loss per 1000' of pipe

Loss in 800' of pipe;  $14.5 \times 800 / 1000 = 11.6$  feet

There are sprinklers which operate under higher pressures and discharge up to 500 gallons per minute, but these are not recommended for South Dakota conditions where winds cause severe variations in distribution of water.

The pressure rating of some sprinklers is expressed as "feet of head." Figure 4 can be used to convert feet of head to pressure in terms of pounds per square inch.

As a general rule, the larger the nozzle, the higher will be the required pressure for good distribution of water. The wetted diameter, or the maximum size circle a sprinkler will wet when no wind is present, will also vary with the nozzle size and pressure. The nozzles can be quickly replaced and different sizes installed.

The sprinkler spacings will vary with the size sprinkler used, as well as with the nozzle size and operating pressure. Because of wind conditions, it is recommended by the Experiment Station that the spacing

of the sprinklers on the lateral should not exceed 30 percent of the wetted diameter, and the maximum distance that a lateral should be moved should not exceed 50 percent of the wetted diameter.

**Fittings.** When a sprinkler system is referred to by a name, the reference is to the manufacturer of the fittings. The pumps, pipe and the sprinkler heads which are made by different manufacturers are assembled by the manufacturer of the fittings and sold under his name.

These fittings include the coupler as well as other fittings such as elbows, pump connections, reducers, increasers, outlet tees, tee type valves, plugs, etc.

All couplers, as well as other fittings, depend upon either one or two replaceable rubber gaskets to prevent the loss of water between the pipe and the coupler when water pressure is present in the pipe. The greatest difference in couplers is the way they are fastened to the pipe.

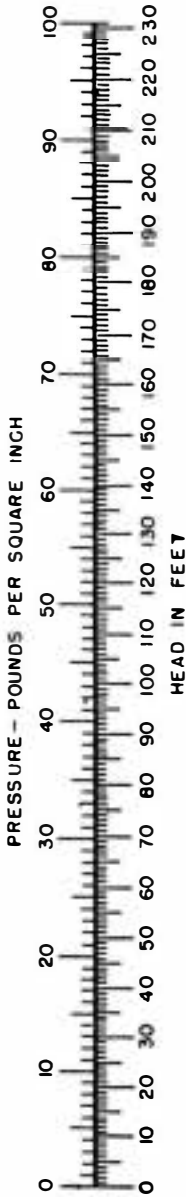


FIGURE 4  
HEAD - PRESSURE CHART

Sample Calculation

Given: Average sprinkler pressure 35 lbs. per sq in.  
 Pressure loss in lateral 15 feet head  
 Pressure loss in main 10 feet head  
 Elevation pump above water 8 feet

Find: Total pressure or pumping head  
 Sprinkler pressure 81 feet  
 Lateral loss- 3/4 of 15 11.2 feet  
 Main loss 10 feet  
 Elevation pump above water 8 feet  
 Total head 110.2 feet

110.2 feet of head is equivalent to  
 47.4 pounds per square inch pressure

ONE pound pressure equals 2.31 feet of head

## System Design

Sprinkler irrigation equipment and operating methods are being continually improved and changed; however, certain standards of performance and criteria for design are fairly well established and accepted.

No attempt will be made in this publication to give all the data necessary to enable a person to design a system for all sets of conditions that may be encountered. Rather, it is the purpose of this bulletin to give modified examples of successful systems which are in operation in South Dakota—their design, method of operation, costs, and labor requirements. This information can be adapted individually to proposed plans for sprinkler irrigation to determine the feasibility of such a system and to ascertain if it would fit in with existing farming practices. Before equipment is purchased, a detailed design should be made by a qualified engineer.

**System 1.** The first typical system which will be discussed is a fully portable system with a stationary

pumping unit. This system was installed primarily to grow alfalfa in a ranching area for a winter feed crop. The water supply was furnished by a large stock water dam. A layout of the system, installed on a 16-acre field, is shown in Fig. 5.

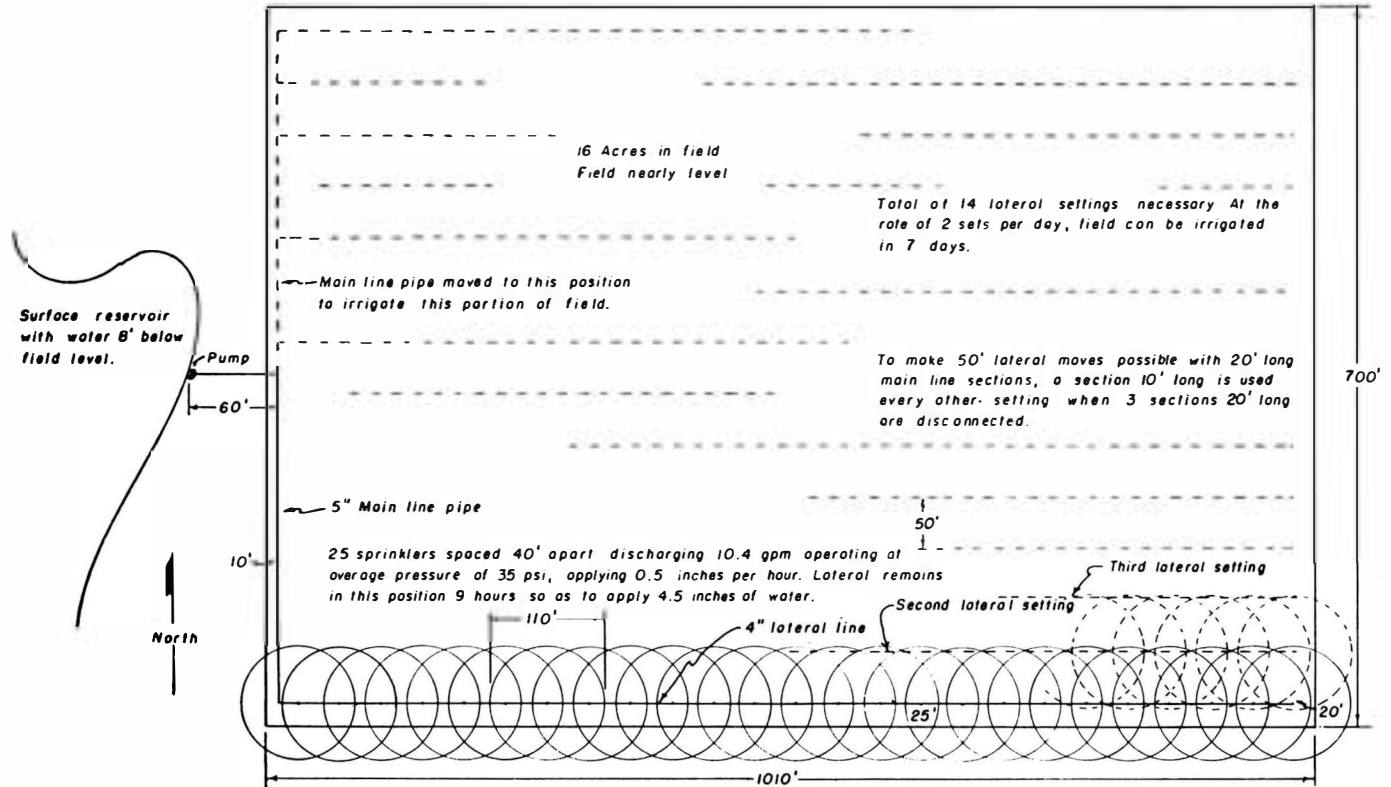
This soil was silt loam approximately 4 feet deep with sand layer below. According to Table 2, the water to be replaced per irrigation on this type soil would be about 3.6 inches. The maximum rate for this soil is 0.7 inch per hour. Table 3 indicates that this rate would require about 15 gallons per minute per sprinkler with sprinklers spaced 40 feet apart on the lateral and moved 50 feet per move. A nozzle which discharged 10.4 gallons per minute per sprinkler was chosen. This is equal to a precipitation rate of 0.5 inch per hour, which is less than the maximum allowed.

The sprinkler, while discharging 10.4 gallons per minute at a pressure of 35 pounds per square inch, has a rated wetted diameter of 100 feet. According to previously mentioned

**Table 3. Precipitation, Inches per Hour for Various Spacings and Nozzle Discharges**

Spacing Feet	Gallons per Minute from Each Sprinkler											
	4	5	6	8	10	12	15	18	20	25	30	35
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
20 x 40	.48	.60	.72	.96	1.20	1.45	1.81	2.17				
20 x 30	.64	.80	.96	1.28	1.60	1.93						
20 x 50	.40	.50	.60	.80	1.00	1.20	1.50	1.80	2.00			
30 x 40	.32	.40	.48	.64	.80	.96	1.20	1.45	1.61	2.01	2.40	
30 x 50	.26	.32	.39	.51	.64	.77	.96	1.15	1.28	1.60	1.92	
30 x 60	.21	.27	.32	.43	.53	.64	.80	.96	1.07	1.54	1.61	1.87
40 x 40	.24	.30	.36	.48	.60	.72	.90	1.08	1.20	1.50	1.80	2.10
40 x 50	.19	.24	.29	.38	.48	.58	.72	.86	.96	1.20	1.44	1.68
40 x 60	.16	.20	.24	.32	.40	.48	.60	.72	.80	1.00	1.20	1.40
40 x 80	.12	.15	.18	.24	.30	.36	.45	.54	.60	.75	.90	1.05
50 x 50	.15	.19	.23	.31	.39	.46	.58	.69	.77	.96	1.15	1.35
50 x 60	.13	.16	.19	.26	.32	.39	.48	.58	.64	.80	.96	1.12
50 x 70	.11	.14	.17	.22	.28	.33	.41	.49	.55	.69	.82	.96

FIGURE 5  
DESIGN I





recommendations that the spacing of sprinklers on the lateral should not be over 30 percent of the wetted diameter and the distance between moves not be over 50 percent of the wetted diameter, it can be seen that the maximum recommended spacing would be 30 x 50 feet. The 40 x 50 foot spacing used exceeds the spacing recommended between sprinklers on the lateral line. This is justified, however, because the irrigated area was protected from sweeping winds by hills on one side and by trees on the other.

To replace the 3.6 inches of water per irrigation as is indicated in Table 2, more water would need to be applied due to evaporation, deep percolation and other unavoidable losses that occur. Under average conditions this system was operated so as to apply 4.5 inches of water to replace 3.6 inches of water in the soil.

To determine how long the system operated at each position of the lateral, the total water needed divided by the rate of application per hour shows that the system should operate nine hours ( $4.5 \div 0.5$ ) in each position. It would be possible to operate so as to have two settings of nine hours each per day and have sufficient time to move the lateral

line and service the pump during daylight hours. This field required a total of 14 lateral settings and the entire field could be irrigated in seven days.

The 3.6 inches of water that the soil will hold would supply the crop for nearly 14.5 days ( $3.6 \div 0.25$ ). This indicates that this system would need to operate only 7 out of 14.5 days. It could be used on other suitable land if it were available. Care should be taken that the entire field does not get to such a low moisture level that the crop will be damaged before the entire field can be irrigated.

The required capacity of the pump is 260 gallons per minute (25 sprinklers x 10.4 gpm per sprinkler). A pump with a capacity of 275 gallons was selected to take care of any differences that might be encountered in fluctuating pumping pressures.

The total head or pressure that the pump must provide would be the sum of the pressures at which the lateral operated, plus the pipe friction in the lateral pipe, plus the main line pipe friction.

In Fig. 2, the lateral pipe friction is found to be 17.2 feet, and in Fig. 3, the main line pipe friction is 5.3 feet. The sprinkler pressure of 35

Table 4. Equipment Used in System I

Quantity	Item	1952 Price
19 .....	20' lengths of 5" mainline pipe .....	\$ 437.00
1 .....	10' lengths of 5" mainline pipe .....	16.00
48 .....	20' lengths of 4" lateral pipe .....	810.00
	Fittings such as elbow, pump connection, plug, etc. ....	47.00
25 .....	Sprinkler heads with discharge 10.4 gpm .....	140.00
	Pump, engine and suction hose .....	987.00
	Total .....	\$2437.00

Table 5. Annual Cost of Irrigating for System 1\*

	Annual Fixed Cost	Annual Operation Cost	Annual Cost per Acre
Depreciation .....	\$192.20	.....	\$12.01
Taxes and insurance .....	24.37	.....	1.52
Interest on investment .....	60.93	.....	3.81
Fuel cost .....	.....	\$ 95.04	5.94
Oil and lubrication .....	.....	7.56	0.47
Repairs .....	.....	9.87	0.62
Total .....	\$277.50	\$112.47	\$24.37
Labor† .....	.....	68 hrs.	4.25 hrs.

\*Method of computation shown in Appendix 1.  
†Includes time required to set up system in the spring and store in the fall.

pounds per square inch is the same as 80.5 feet of head. The suction lift is 8 feet.

In order to compute the head that must be supplied at the point the lateral connects with the main, the average operating head is added to three-fourths the head loss in the lateral line. In this case the head supplied to the lateral must be 80.5 + ¾ of 17.2 or 93.4 feet. Adding the main line friction loss and the suction lift (93.4 + 5.3 + 8.0) a total pumping head of 106.7 feet is supplied.

A pump was therefore selected that had maximum efficiency while pumping 275 gallons per minute at a pumping head of 107 feet. A list of the equipment used in System 1 is given in Table 4.

The operator of this system irrigated the 16 acres three times during a normal year, applying 4.5 inches per irrigation, making a total 13.5 inches an acre, or 216 acre inches of water for the entire field per year. The over-all pump efficiency was 70 percent and was powered by a stationary engine. The total fuel cost was 44 cents per acre inch of water applied.<sup>3</sup> Table 5 gives a summari-

zation of the irrigation costs for this system.

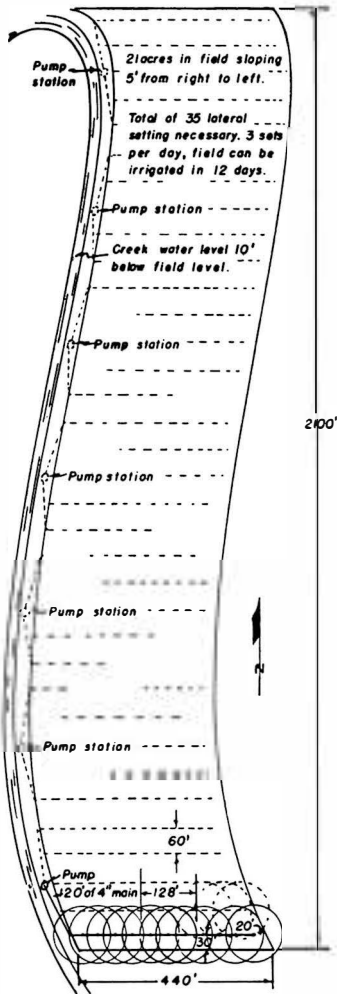
The cost per acre inch of water applied would be \$1.81 and would require 0.31 hours of labor.

System 2. The second system is a fully portable system. The pump is mounted directly on a tractor which, through a power take-off, provides power to the pump. The water supply is a spring-fed creek. How this system was set up in a 21-acre field is shown in Fig. 6.

A minimum of equipment is needed in this sort of layout. There are seven different pumping locations and five lateral settings can be made from each pump setting. In this manner, very little main line pipe is needed and yet the pump need not be moved every time the lateral is moved. The 120 feet of main line pipe could be eliminated if the pump station were changed each time the lateral setting was moved. Under the conditions encountered with this particular system, some difficulty was encountered in getting good pumping sites along the creek; therefore the 120 feet of main

<sup>3</sup>Method of computation is shown in Fig. 8 in the appendix.

FIGURE 6  
DESIGN 2



11 sprinklers spaced 40' apart discharging 25.4 gpm operating at average pressure of 40psi, applying 1.0 inches per hour. Lateral remains in each position 4 hours so as to apply 4" of water.

Lateral line made up of 220' of 3" and 200' of 4" pipe.

line pipe was used to keep the number of pumping sites to a minimum.

This soil was a fine sandy loam soil about 4 feet deep which would hold about 3 inches of water for crop use between irrigations and which had an infiltration rate of over  $1\frac{1}{2}$  inches per hour.

Table 3 indicates that sprinklers discharging 25 gallons per minute spaced 40 feet apart and moved 60 feet per move would be equal to a precipitation rate of 1.0 inch per hour, which is less than the maximum amount for this soil. The type sprinkler used discharged 25.4 gpm operating at an average pressure of 40 pounds per square inch. This sprinkler wets a circle 128 feet in diameter. According to previously mentioned recommendations that the spacing of sprinklers on the lateral line not be over 30 percent of the wetted diameter and the distance between moves not over 50 percent of the wetted diameter, it can be seen that the maximum recommended spacing would be 38.4 feet by 64 feet. The spacing used, 40 by 60 feet, meets the recommended values. The sprinkler used applies slightly more than an inch per hour which is also within recommended limits.

To replace 3 inches of water in the soil under average conditions, 4 inches of water was applied per irrigation. This required the lateral to be moved once every four hours. The pumping unit was supplied with enough fuel to last just four hours. The lateral was moved at about seven o'clock in the morning. It would stop four hours later when

the fuel supply was depleted. The pipe was moved at noon, and at seven o'clock in the evening, with the amount of fuel replaced regulating the pumping time. In this manner, three sets per day were completed and the moving time fit in well with other farming operations.

The entire field required a total of 35 lateral settings, thus requiring nearly 12 days ( $35 \div 3$ ) to irrigate the entire field. During hot weather an alfalfa crop would deplete the moisture in  $12\frac{1}{2}$  days ( $3.1 \div 0.25$ ). This system would therefore supply irrigation water rapidly enough to supply ample water during any dry season.

In order to get a minimum investment in equipment per acre a design such as this where the system is in operation nearly every day must be made. However, this system could be operated more than the 12 hours per day as it has been designed. It could have four lateral settings per day and thus the field could be covered in nine days. This would probably necessitate moving pipe in darkness which is undesirable under ordinary circumstances. A list of the equipment used is presented in Table 6.

In pump selection the total head under which the pump is operated must be calculated. In this setup the following heads of water are present:

- Average operating head—92.0 feet
- Lateral line friction loss—11.7 feet
- Difference in elevation of ends of lateral—5 feet

To compute the head that must be supplied at the point the lateral connects with the main, the average operating head is added to three-fourths the head loss in the lateral. In this case the head supplied to the lateral must be  $92.0 + \frac{3}{4}$  of  $11.7 + 5$  feet difference in elevation, or 105.8 feet. It should be noted that in this case the lateral line friction loss was considerably less than the maximum allowable 20 percent as is recommended. This was done in order to compensate for the fact that the lateral was laid uphill 5 feet. The maximum main line loss would be 5 feet, the suction lift was 10 feet; therefore the total head was 121 feet. A pump was selected that had maximum efficiency while pumping 280 gallons ( $25.4 \times 11$ ) of water per minute at 121 feet of total head.

The operator of this system irrigated the 21 acres in the field four

Table 6. Equipment Used in System 2

Quantity	Item	1952 Price
6.....	20' lengths of 4" Main line pipe .....	\$100.00
10.....	20' lengths of 4" Lateral line pipe .....	170.00
11.....	20' lengths of 3" Lateral line pipe .....	130.00
	Fittings—pump connection, elbows, reducer, plug, etc. ....	33.00
11.....	Sprinkler with gpm discharge .....	87.00
	Pumping unit and suction hose* .....	320.00
	Total .....	\$840.00

\*This includes only the pump. Power was furnished by a farm tractor which was not included in the cost.

Table 7. Annual Cost of Irrigating for System 2\*

	Annual Fixed Cost	Annual Operation Cost	Annual Cost per Acre
Depreciation .....	\$60.38	-----	\$ 2.88
Taxes and insurance .....	8.40	-----	.40
Interest on investment .....	21.00	-----	1.00
Fuel cost .....	-----	\$255.36	12.16
Oil and lubrication .....	-----	11.20	0.53
Repairs .....	-----	25.54	1.22
Total .....	\$89.78	\$292.10	\$18.19
Labor .....	-----	126 hrs.	6 hrs.

\*Cost excludes the cost of power unit which was a farm tractor.

times per season, applying 4 inches per irrigation, making a total application of 16 inches per acre. The pump and pump drive efficiency were low in this system, being only 55 percent. The fuel cost for this unit was about 76 cents per acre inch of water applied. Table 7 is a summarization of the irrigation costs for this system.

The cost of applying one acre inch of water would be \$1.14 and would require 0.38 hours of labor.

System 3. This system is a semi-portable type in which the main lines are left in place throughout the season. They may or may not be buried below the ground. In this system, outlets are provided with valves, made to accommodate the laterals, and are located every 50

feet on the main line. Figure 7 shows a layout of this system installed on a 40-acre field, and a list of equipment used is given in Table 8.

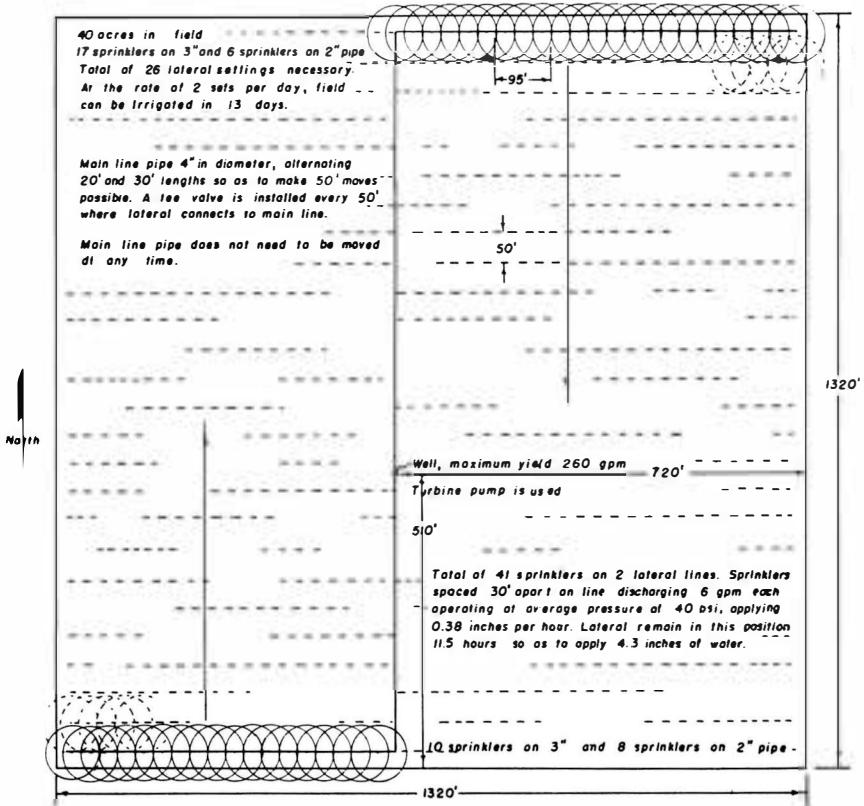
A minimum of labor is needed with this sprinkler system which is commonly referred to as the "split lateral" system. During the first irrigation, the lateral on the east side is moved south and the west lateral is moved north. For the second irrigation, the east lateral is moved north and the west lateral south.

By using tee valves, one lateral can be moved while the other is operating. With the split lateral, short laterals are feasible, enabling the use of relatively small pipe. Two lengths of 2- or 3-inch pipe can easily be carried at one time by a man or a teen-aged boy. The moving

Table 8. Equipment for Design 3

Quantity	Item	1952 Price
25 .....	20' length 4" Aluminum Main line pipe .....	\$ 415.00
25 .....	30' length 4" Aluminium Main line pipe .....	575.00
27 .....	30' length 3" lateral line pipe .....	486.00
14 .....	30' length 2" lateral line pipe .....	188.00
22 .....	Extra for tee's on main line .....	260.00
	Fittings, pump connections, reducers, elbow plugs .....	42.00
41 .....	Sprinkler heads with 6.1 gpm discharge .....	235.00
	TOTAL .....	\$2201.00
	Cost of pumping unit and well .....	2100.00
	TOTAL COST .....	\$4301.00

FIGURE 7  
DESIGN 3



time for each lateral on this system is about 20 minutes for one man. Thus each lateral could be in operation, if necessary, 23 hours and 20 minutes each day, if it were moved twice daily.

The quantity of the water that is to be carried by a main line of this type is lower than that required of other systems. If the water supply is equal distance from the north and south field boundaries, the main line would have to carry one-half the total quantity of water in each direc-

tion. By cutting down the quantity of water carried in a pipe, smaller pipe with lower friction loss can be used resulting in a saving on the original purchase price.

This system was used on a deep clay loam that had a water-holding capacity of nearly 5 inches of irrigation water and had an infiltration rate of about one-half inch per hour. This system used sprinkler heads that discharged 6 gallons per minute while operating at 40 pounds per square inch. This resulted in a

wetted diameter of 95 feet. The sprinklers were spaced 30 feet apart on the lateral and moved 50 feet each move. With a discharge of 6 gallons per minute this would result in a precipitation rate of 0.38 inch per hour, which is below the maximum for this soil and is above the minimum recommended for South Dakota conditions. The recommended minimum is 0.3 inch per hour.

The recommended spacing for sprinklers on the lateral of not over 30 percent of wetted diameter is nearly fulfilled with this system: 30 percent of 95 feet (28.5 feet) is 1.5 feet less than the 30-foot spacing used. The recommended move of the lateral, 50 percent of the wetted diameter, is exceeded slightly with this system. Fifty percent of the wetted diameter (95 feet) would be 47.5 feet compared to the move of 50 feet.

This system was operated continuously, using two sets per day. By doing this the lateral was operated 11½ hours at each position, applying 4½ inches (11½ x .38) of moisture. The laterals were moved in the morning and in the evening, requir-

ing less than one hour's time for each move.

A total of 26 lateral settings are required to cover the entire field, which would mean that the field could be irrigated in 13 days, applying the 4.3 inches. The water used by an alfalfa crop, one of the heaviest users, during peak conditions would be about 3.25 inches (13x.25) per irrigation, leaving (4.3-3.25) about 1 inch of water per irrigation for deep percolation, evaporation, and other unavoidable losses. This analysis shows that the system is adequate for the acreage that it is designed to cover.

It might be noted that only 4.3 inches of water are applied, while the water-holding capacity of the soil for irrigation water is at least 5 inches. In this case it would be difficult to apply 5 inches, because that would require the lateral to be 13 hours ( $5 \div 0.38$ ) in each position. This would make it impossible to have two sets per day. A heavier rate of application could have been used so as to make possible a 5-inch application of water, plus losses per 11-hour setting, but the well would not yield sufficient water for this.

Table 9. Annual Cost of Irrigating for System 3\*

	Annual Fixed Cost	Annual Operation Cost	Annual Cost per Acre
Depreciation .....	\$285.00	.....	\$ 7.12
Taxes and insurance .....	42.95	.....	1.07
Interest on investment .....	107.37	.....	2.68
Fuel cost .....	.....	\$275.20	6.88
Oil and lubrication .....	.....	19.20	0.48
Repairs .....	.....	27.52	0.69
Total .....	\$435.32	\$321.92	\$18.92
Labor.....	.....	150 hrs.	3.8 hrs.

\*Cost includes the cost of the well.

In selecting a pump, the following calculated heads are present:

Average operating head 40 pounds per square inch—92 feet.

Lateral line friction loss 8 pounds per square inch—18 feet

Pressure required in the main at the lateral— $92 + \frac{1}{4}$  of 18=105.5 feet

The maximum main line loss is 10 feet. This was designed to be low because the lateral lines will be different distances from the water supply, causing the lengths of mains to be different for the two laterals. By designing the main line with low friction loss the pressure in the main at the lateral tee valve will not vary to any great degree.

The total operating head, exclusive of suction head, would be 105.5 + 10 or 115.5 feet.

The well yielded a maximum of 280 gallons per minute, with the water level 43 feet below the ground surface during pumping operations. This necessitated a turbine pump which delivered the needed quantity of water under 149.5 feet (115.5 + 34) of head.

The operator of this system irrigated the 40-acre field four times during an average season, applying 4.3 inches per irrigation, making a total application of 17.2 inches per year. The turbine pump which was installed in the well was powered by a stationary gasoline engine, using a gear-head drive. The over-all plant efficiency was 63 percent. The fuel cost for this installation was 40 cents per acre inch of water pumped. Table 9 is a summarization of the irrigation costs for this system.

The cost to apply one acre inch of water would be \$1.10 and would require 0.21 hours of labor.

## Summary

The design of a sprinkler irrigation system must meet certain well established principles in order to be successful. There are several factors that must be considered.

- (1) Quality and quantity of water
- (2) The soil
- (3) The pumping unit
- (4) Main line and lateral line friction loss
- (5) Wind

Omitting any of these factors can cause excessive irrigation costs with relatively poor crop return.

Three typical sprinkler irrigation systems were discussed. No attempt was made to compare one system with another because different conditions were encountered in each instance. The size and shape of the field, the type and location of the water supply, the soil, and the total amount of irrigation water applied per season will cause irrigation costs to vary.

System 1 was a fully portable system with a stationary pumping unit and the water supply at one end of the field. This system did not need to be in operation at all times in order to supply the needed irrigation water. The field was comparatively small which would cause a relatively high annual cost per acre.

System 2 was a fully portable system in which the pumping station was moved several times during an



irrigation. A farm tractor which was ordinarily idle during the irrigation season was used on the pump. A minimum of initial capital is needed in this type of a system, but the labor requirement and the fuel costs ordinarily run high.

System 3 was a semi-portable system using the split lateral layout

with permanent mains. A minimum of labor is needed with this system, although the initial capital investment is higher than with other systems. The 40-acre field in this system had the well located near the center of the tract which helped to reduce the amount of equipment needed.

## Appendix I

### Sprinkler Irrigation Costs

Irrigation costs are usually expressed as an annual cost and are made up of these parts: fixed costs on equipment, operating costs, and labor costs.

**Fixed Costs.** Fixed cost on equipment is that due to depreciation, interest on investment, taxes, and insurance on equipment. They are affected very little by the extent the equipment is used. If the equipment were idle for a season the equipment would depreciate nearly as much as if it were used; interest on investment and insurance is not affected by the number of hours operated.

Because the fixed costs are nearly identical irrespective of hours of operation, the greater number of acre inches of water required of a system per year, the lower the cost per acre inch of water applied.

The depreciation cost is dependent upon the expected life of the equipment. The annual depreciation cost is the total cost divided by the life expectancy. Table 10 gives an estimate of the useful life of equipment when operated under

average conditions. In some cases, such as with the turbine pump, an average of all the parts is taken instead of dividing it into increments and figuring each part separately.

Interest on the investment is often omitted when computing annual costs. If the money is borrowed, the interest on the investment is computed at a borrowed rate of interest. If it is not borrowed, it is figured at the interest rate the money would earn if it were placed at some alternative use. The method generally used to compute interest charges is

Table 10. Estimated Useful Life of Irrigation Equipment

Item	Estimated Useful Life in Years
Aluminum pipe .....	20
Galvanized pipe .....	15
Sprinkler heads .....	5
Well and casing .....	20
Centrifugal pump .....	15
Turbine pump .....	12
Gasoline engine (water cooled) .....	10
Diesel engine .....	14
Gasoline engine (air cooled) .....	5
Propane engine .....	14
Power transmission	
Gear head .....	15
V-belt .....	3
Flat belt leather .....	10
Flat belt rubber and fabric .....	5

to multiply one-half of the initial cost of the plant by the interest rate.

Taxes and insurance costs vary considerably in different localities. Often no insurance is carried, and the mill tax rate varies according to localities. The usual method of computing the combined costs is based on 1 percent of the initial cost of the plant.

**Operating Costs.** The operating costs of an installation are taken up primarily by the pumping unit. In isolated cases the water supply may be in an elevated position so that no pump is necessary. This would be an exception. Operating costs can be divided into cost of fuel, lubricants, and repairs.

**Fuel Costs.** Fuel costs will vary with the over-all plant efficiency, the kind of fuel used and type of power unit.

The over-all plant efficiency is based on the efficiency of the pump and of the drive from the power unit to the pump. The drive from the power unit to the pump is oftentimes a direct drive which would be 100 percent efficient. A V-belt drive, a flat-belt drive, or a gearhead drive will seldom be over 90 percent efficient. The over-all plant efficiency, is the product of the pump and the drive efficiency.

Figure 8 can be used to determine the fuel cost per acre inch of water applied. The number of horsepower hours per gallon of fuel that the engine will deliver can be determined from tests run by the manufacturer or, for estimates, the following figures can be used:

Type Engine	HP Hours Per Gallon of Fuel
Engine using propane .....	5 to 7
Gasoline engines in poor repair .....	6 to 7
Gasoline engines in good repair .....	8 to 10
High speed diesel .....	11 to 15

The cost of lubricating oils is usually estimated to be about 2 cents per hour of operation.

Repair costs are very difficult to estimate. The first few years of operation the cost will be low but will increase as the system gets older. However, the costs should be distributed equally throughout the expected life of the equipment. The repair costs of the pipe, sprinklers and fittings are negligible in comparison to the repair cost of the power unit. For this reason, the total repair cost is determined by the length of time the engine is in operation. Fuel costs will also be dependent upon the number of hours operation; therefore, repairs are usually figured on the basis of the cost of fuel. Normally the repair cost varies with the type of power in this manner:

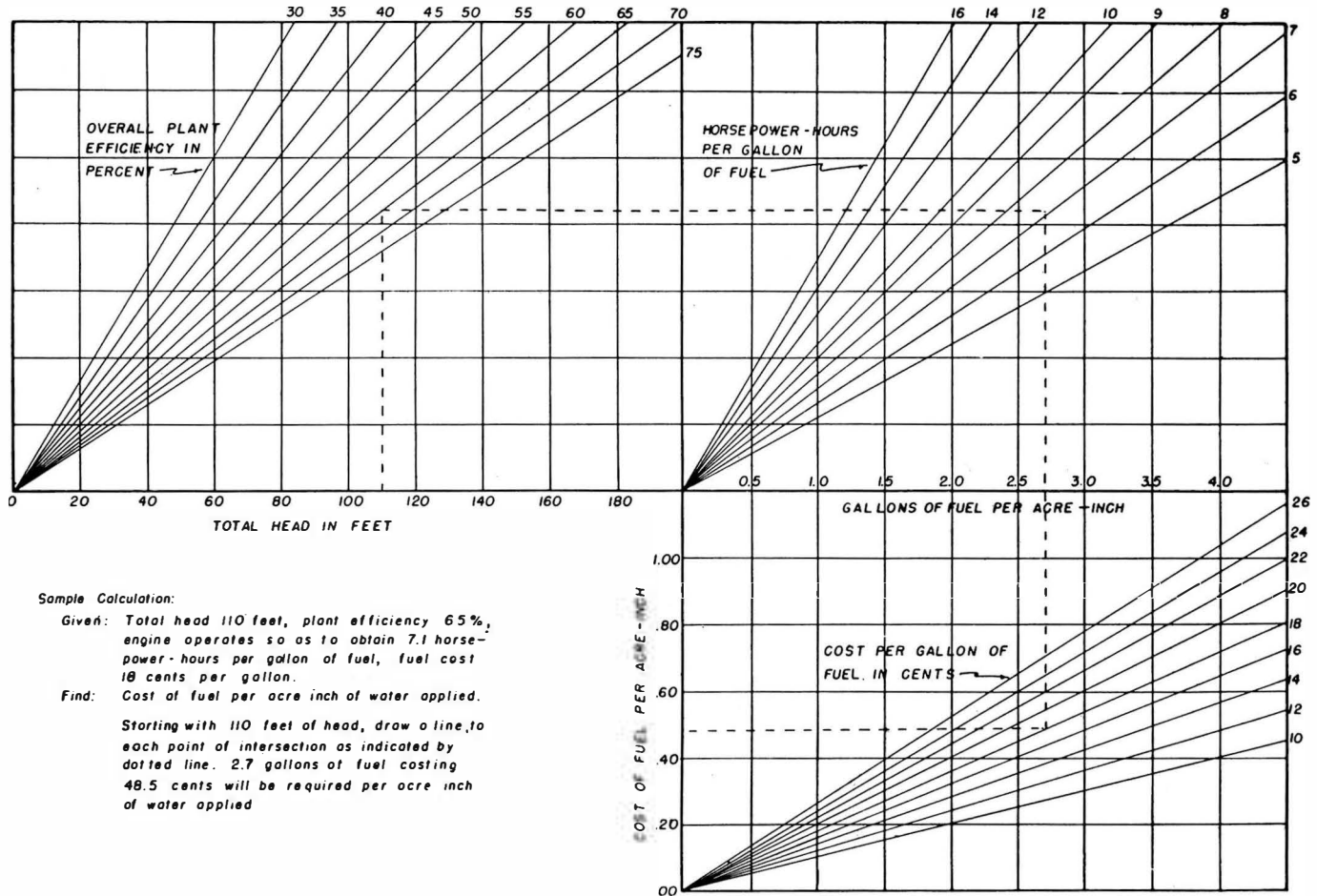
Type of Power	Repair Cost
Electric motor ..	5% of annual cost of electricity
Propane engines .....	7% of annual cost of fuel
Gasoline engines ..	10% of annual cost of fuel
High speed diesel .....	25% of annual cost of fuel

**Labor Costs.** Labor costs will vary with the crop irrigated, type of soil, as well as the type and size of the system.

A pasture or hay crop requires less time for moving pipe than a taller growing crop such as sorghums or corn. Soils which do not stick to hands and shoes are much pleasanter to work in and require less moving time.

FIGURE 8

FUEL COST OF PUMPING WITH INTERNAL COMBUSTION ENGINES



Sample Calculation:

Given: Total head 110 feet, plant efficiency 65%, engine operates so as to obtain 7.1 horsepower-hours per gallon of fuel, fuel cost 18 cents per gallon.

Find: Cost of fuel per acre inch of water applied.

Starting with 110 feet of head, draw a line to each point of intersection as indicated by dotted line. 2.7 gallons of fuel costing 48.5 cents will be required per acre inch of water applied

Split line lateral systems generally are easier to move because smaller pipe is required and the main line pipe need never be moved. A system which requires moving the pumping plant as well as the main and lateral pipe will have a high labor cost. There is on the market a wheel move and tractor move system that cuts down labor requirement but has a higher initial cost of equipment. The pumping plant also needs some daily attendance for lubrication, refueling and inspection.

This time is higher for engine-driven plants than for electrically driven plants. It is estimated that 5 percent of the total operating time is needed for pumping plant attendance for a gasoline engine and 2 percent for an electrically driven plant.

An average system now in operation indicates that the total labor requirement is one man hour per irrigation per acre. Less labor is required in the larger systems with split line laterals, with valve in line tees, and permanent mains.

## Appendix II

### Minimum Requirements for the Design, Installation and Performance of Sprinkler Irrigation Equipment as Recommended by the American Society of Agricultural Engineers<sup>1</sup>

These minimum requirements pertain to the design, installation, and performance of sprinkler irrigation equipment, and include dealer-purchaser responsibilities. The design and performance requirements are concerned particularly with those factors that are directly related to land, crops, and farm operations. The dealer-purchaser responsibilities recognize successful operation of a sprinkler system as depending on both buyer and seller.

#### Part I. Design and Performance

1. **Application Rate.** A portable sprinkler irrigation system, when properly designed and operated, shall meet the following conditions with respect to water application:

(a) Apply water at a rate which does not cause runoff during the normal operating period nor cause

water to stand on the surface of the ground after the sprinkler line is shut off.

(b) Determination of the proper rate of application shall be the responsibility of the person designing the system. Values for bare ground infiltration rates for different types of local soils may be obtained from responsible agricultural technicians. In the absence of such technical advice, the designer may estimate the proper application rate on the basis of past experience with similar soil types.

2. **System Capacity.** (a) For regularly irrigated areas, the system shall have the capacity to meet the peak moisture demands of each and all crops irrigated within the area for which it is designed. Sufficient time must be allowed for moving laterals

<sup>1</sup>*Agricultural Engineering*, March 1951, p. 166.

and for permitting cultural practices on the land. The capacity must also allow for reasonable water losses during application periods with the system operating in accord with design conditions.

(b) For supplemental irrigation and/or special uses, the system shall have the capacity to apply stated amount of water to the design area in a specified net operating period.

3. **Depth of Water Application.** In the design of the system, total depth of application (equivalent rainfall) per irrigation shall be governed by the capacity of the soil for moisture storage and the depth of the principal root zone of the crop irrigated. Information on both of these factors may be obtained from agricultural technicians or may be estimated by the designer on the basis of his past experience with similar soil types and crops.

4. **Uniformity of Water Application.** Since uniformity of water application is affected by both pressure in the line and spacing of sprinklers, recommendations for desirable operating pressures and spacings for different types of sprinklers and nozzle sizes shall be obtained from the sprinkler manufacturer.

Differences in pressures at the sprinklers shall be kept to a minimum to assure reasonably uniform distribution of water over the entire design area. A common rule, which should be adhered to as closely as practicable, is to limit pressure differences along a sprinkler lateral to 20 percent of the higher pressure.

Excessive pressure differences in the main or supply line result in

widely varying pressures at the head of the laterals. In many instances these excessive variations cannot be controlled by pipe size alone. Then the only practical alternative is to design for adequate pressure at the lateral take-off where pressure in the main will be lowest, and instruct the operator in regulating pressures into the other laterals by adjusting the take-off valve openings.

5. **Crop Damage.** Water shall be applied in a manner which will not cause direct physical damage to plants or fruit.

## **Part II. Dealer-Purchaser Responsibilities**

### *A. Dealer Responsibility*

1. **Proper Design.** When the system is planned by a dealer, or his representative, the dealer shall assume full responsibility for the proper design of the system he proposes to furnish. Design requirements to fit the system to conditions of soil, topography, water supply and crop enterprise shall be ascertained by the dealer either directly or by obtaining such information from recognized reliable sources.

When design requirements are furnished in writing by the purchaser, the dealer's responsibility shall be limited to the design of the system to meet stated conditions.

When plans and specifications are furnished in writing by the purchaser, the dealer's responsibility shall be limited to supplying equipment which will satisfy the requirements

of the specifications furnished. If the purchaser buys the system piece-meal, he absolves all dealers of responsibility for the performance of the system as a unit.

2. **Proper Installation.** The dealer or his representative shall assume full responsibility for the proper installation of the system.

Pumps and power units shall be set on a firm base and care shall be taken to keep the pump and the motor or engine in proper alignment.

Wiring and starting equipment for electrically operated plants shall comply with approved standards. Electric motors shall be provided with overload and low-voltage protection.

Internal-combustion engines shall be provided with protective devices. Thermostats shall be supplied that stop the engine when water or oil temperatures exceed the safety point. Where conditions are such that a failure of the water supply might result in the pump losing its prime, the pumping plant shall be protected by a device that stops the engine. These devices may be dispensed with where conditions are such that there is little probability of water supply failure, or when the pumping plant is constantly attended.

3. **Operating Instructions.** The dealer or dealers furnishing equipment required for a complete sprinkler system shall furnish to the purchaser, in writing, such instruction, performance charts and layout drawings as are required to insure

proper operation, in accord with design conditions and normal expected life for the type of equipment furnished.

4. **Performance Warranty.** When a dealer or associated group of dealers assumes responsibility for the design and installation of a sprinkler irrigation system, a warranty shall be furnished, stating specially the performance expected for water-application rate, capacity, rate of coverage for a specific design area serving specific crops and crop acreages as stated by the purchaser and mutually understood to be the basis of design.

Warranty shall be based on trial of the system during operation under the range of operating conditions imposed on the system. The warranty shall not be expected to cover any conditions encountered which were beyond reasonable control of the dealer either in design or installation. Values used for infiltration rate, peak-use rate of moisture by crops, or capacity of soils to retain water for plants cannot be expected to be accurate for every local condition of soil. Evidence that the dealer has made reasonable efforts to obtain values from reliable sources shall be sufficient reason to absolve him from responsibility if such values do not represent local conditions.

When a dealer or dealers assume responsibility for the installation of a system in accord with specifications supplied by the purchaser, a warranty shall be furnished, stating the performance expected as to friction loss in the system, pump and

engine motor characteristics, and other pertinent data pertaining to the specifications.

5. **Equipment Warranty.** The dealer or dealers assuming responsibility for the installation of the system shall furnish warranties covering the quality of material and workmanship of each piece of equipment furnished in accord with the original manufacturer's guarantee, and shall provide for replacement of defective parts shown to have failed because of poor quality materials or poor workmanship.

6. **Maintenance and Repair Service.** Dealers selling sprinkler irrigation systems in a territory shall maintain an inventory of replaceable parts and required equipment repair service. The extent of this available service shall be such that users in the territory will be assured of reasonable service which will avoid crop loss due to shutdown of a system for replacements or repairs.

#### *B. Purchaser Responsibility*

1. **Operations in Accord with Instructions.** The purchaser and user of a sprinkler irrigation system shall assume responsibility for failure of the system to perform properly if, after receiving all data furnished by the dealer, he fails to operate the system in accord with all conditions assumed in the design of the system. To obtain the full life of all equipment the user shall observe the stated limits of operating conditions set forth by the manufacturer.

2. **Care and Maintenance Recommendations.** The purchaser shall fol-

low the dealer's recommendations for care and maintenance of the equipment. This applies to periods of use as well as non-use of the equipment.

### **Part III. Definitions**

**Design Area.** The specific land area which the supplier or designer and the purchaser mutually understand is to be irrigated by the sprinkler system.

**Sprinkler Irrigation System.** This includes all equipment required to apply water to the design area, from the source of water supplying the system to the revolving sprinkler, nozzles, or perforated pipe.

If the water is already available to the design area, the system includes only the equipment required to develop the necessary pressure and apply the water to the area.

If both water and pressure are available, as in the case of an existing pressure line, the system includes only the equipment required to take water under pressure from the supply line and apply it to the design area.

**Sprinkler Lateral.** A line of portable pipe or tubing with sprinklers, nozzles, or perforations along the line. A lateral may be one of several operated from a common main supply line, or it may be a single unit supplied directly from the water source.

**Application Rate.** The equivalent rainfall rate expressed in inches of water depth per hour (acre-inches per acre per hour). For systems with rotating sprinklers, the rate is com-

puted on the basis of the spacing of lateral settings, the spacing of the sprinklers along the lateral, and the average discharge of the sprinklers. For perforated pipe systems, the application rate is computed from lateral spacings, length of lateral, and average flow into the lateral.

**Infiltration Rate.** The rate at which soil will take in water during the irrigation period, expressed in

inches of water depth per hour (acre-inches per acre per hour).

**Peak Moisture Demand.** Peak moisture demand of any crop is considered to be the maximum that occurs during periods of maximum temperature and crop growth. This peak demand for moisture on the part of a crop results from transpiration by the plants, and direct evaporation from the soil.