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Evaluation of Sprinkler Systems in Northern Utah

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EVALUATION OF SPRINKLER SYSTEMS

IN NORTHERN UTAH

by

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INTRODUCTION

Sprinkling as a method of irrigation has been expanding rapidly in the United States, with acreages irrigated by this method increasing every year. One of the major reasons for the expansion is the great improvements that have been made in sprinkler irrigation equipment. Light weight aluminum pipe, with quick couplers, improved pump and motor efficiencies have all made sprinkler irrigation more desirable. High efficiency of water application, labor requirements, and favorable plant response have also favored the expansion.

Another reason for the increase in sprinkler irrigation is that new lands being brought under irrigation are often not adaptable to surface irrigation. Farmers are turning to sprinkler irrigation on these lands that are not generally suitable to surface methods. Conditions not suitable for surface irrigation are rough rolling land which require heavy land leveling, steep slopes that cannot be irrigated safely because of erosion, highly permeable soils difficult to irrigate efficiently by surface methods, and shallow soils that cannot be safely leveled.

There are still many questions to be answered concerning the design and operation of sprinkler systems as a result of this rapid expansion; the purpose of the study reported herewith is to supply some of these answers. Features of sprinkler irrigation studies in this investigation are, distribution and application efficiencies, water losses, labor requirements, and general design characteristics of the system.

Many farmers do not attain the maximum benefit from their sprinkler irrigation systems. Some systems were never designed properly. In other cases the farmer uses the system in a much different way than that for which the system was designed. This report contains factual data which shows the preceding statement to be true for a great many systems in the area studied.

Objectives of study

There are five main objectives to this investigation:

1. Determination of the effect of wind, operating pressures, and spacing of sprinklers and laterals on water distribution.

2. Influence of temperature and relative humidity on water losses between the sprinkler nozzles and that stored in soil.

3. Determination of application efficiencies from the distribution efficiencies and water losses, and development of an average value which it might be expected under Northern Utah conditions.

4. To obtain labor requirements of sprinkler irrigation systems in Northern Utah.

5. To check and evaluate the design of each individual system with respect to lateral efficiency, minimum irrigation frequency and length of set.

Definition of terms

Water losses. The water losses are equal to the average depth of application as calculated from the discharge of the sprinklers on each side of the gaging and minus the average depth of water reaching the ground, as measured in the cans, expressed as a percent.

Minimum depth. The average in the 25 percent of the cans receiving the least adjusted water depths.

Distribution efficiency. The average minimum depth of catch divided by the average depth of catch, expressed as a percent.

Application efficiency. The average minimum depth of catch (25 percent of area) divided by the average depth as discharged from the sprinkler nozzles adjacent to the gaging area, expressed as a percent.

Consumptive Use. The sum of the volumes of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from the adjacent soil, snow, or intercepted precipitation on the area in any specified time divided by the given area, expressed as acre-inches per day.

Wilting point. The soil moisture level in percent of oven-dry weight of the soil at which plants permanently wilt.

Field capacity. The upper limit of soil moisture that is available to the plant.

Readily available water holding capacity. In this report 75 percent of the total available water between field capacity and wilting point is considered as readily available to the plants.

Minimum frequency. The readily available water holding capacity of the root zone divided by the maximum daily consumptive use.

Test area. The area bounded by adjacent sprinklers along a lateral and extending out at right angles as far as the water is thrown. The gage cans are placed symetrically within this area.

Review of literature

At Utah State Agricultural College in 1953, Fuhriman (5) made sprinkler studies similar to those herein reported. His work concentrated mainly on labor time and motion studies connected with this method of irrigation. The results show that labor requirements under Utah conditions was much less of a problem than originally anticipated. These requirements were low, ranging from .05 to .32 man-hours per acre-inch of water applied.

Dusenberry (4) reporting on 53 systems in Montana showed a labor requirement of .75 man-hours per acre-inch of water applied to hay and grain and 1.1 man-hours per acre-inch to row crops.

Becker (1) reported an average labor cost of .59 man-hours per acre-inch of water applied by sprinkling in 1950 in the Willamette Valley, Oregon. The average time per setting was 7.5 hours.

Christiansen (2) in 1942 carried out extensive studies on sprinkler irrigation equipment. His report thoroughly covered hydraulic design. This work is used largely as the basis for sprinkler design today.

Christiansen's report also includes data on labor costs, distribution uniformity, and evaporation losses. His labor cost studies on 37 farms in Sacramento Valley, California, showed a range from 1.0 to 3.7 man-hours per acre-inch of water applied, with an average of 1.5 man-hours per acre-inch. The data he reported on distribution uniformity is too comprehensive to include here, but it showed the adverse effects of inadequate and excessive pressures, wind, non-uniform sprinkler rotation, and sprinkler spacing on the uniformity of distribution. His water losses varied from a minimum of less than 10 percent to a maximum of 42 percent, but he concluded that the actual water loss by evaporation from the spray did not exceed 2 percent.

EVALUATION PROCEDURE

Selection of farms

Tests were obtained on all available farms in northern Utah. No particular feature of the farm or the sprinkler system influenced the selection. Tests were completed on 34 farms.

General procedure

To evaluate the systems under the objectives outlined in the introduction, required obtaining the following.

1. The water application and distribution efficiency
2. The available water holding capacity of the soil
3. The operating procedure used by the farmer
4. The operating characteristics of the system
5. Climatic conditions
6. An analysis of the data obtained

Physical measurements

Nozzle pressure. Pressures were measured at the first and last sprinkler along the lateral and at the sprinklers adjacent to the test section. The measurements were made at the nozzle tip with a pitot tube and a pressure gage. The pitot tube was inserted into the water jet issuing from the nozzles (figure 1), and the pressure gage read to the nearest pound per square inch.

The pressure gage used was tested with a dead weight gage tester and was found to be accurate within one-half pound per square inch, within the range from 15 to 60 pounds per square inch.

Discharge. Discharge measurements were made volumetrically at the same sprinklers as were the pressure measurements. Rubber hoses, 3/4-inch in diameter placed loosely over the nozzles, directed the water into a ten-gallon can. A stop watch was used to measure the time required to fill the can (figure 2).

In using this method of obtaining discharge, care must be taken in placing the hose over the nozzles. Placing a tight fitting hose over the nozzles forms an enlargement in the flow path, which creates a low pressure area. Such a low pressure area will increase the discharge to something greater than normal.

The accuracy of the method used in obtaining the discharge measurements as reported here were checked by installing a water meter in the line (figure 3), and checking the discharge with the hoses, both off and on. This test showed that with the size and length of rubber hose used, 3/4-inch by 6 feet, the error in discharge measurement was insignificant. In making the check, a pressure gage was installed in the riser (figure 3) to determine if the discharge listed by the manufacturer was based on nozzle-tip pressure or by a pressure gage installed in the riser. The results showed that the published discharges were based on pressure measured in the riser. Thus the measured discharge and calculated discharge, based on measured pressure using the pitot tube, do not check exactly. The pressure, as measured with the pitot tube, is always slightly less than exists in the riser.

Distribution of application. Quart oil cans with the tops removed were distributed uniformly throughout the test area, spaced 10 feet apart (figure 4). The cans were placed directly on the ground except where foliage would prevent an accurate catch. In fields of tall crops, the cans were attached to a stake with an elastic band (figure 5).

Figure 1. Method of measuring nozzle pressure with a pressure gage, and pitot tube attachment

Figure 2. Method of obtaining nozzle discharge volumetrically, using 3/4-inch rubber hoses and a 10-gallon can

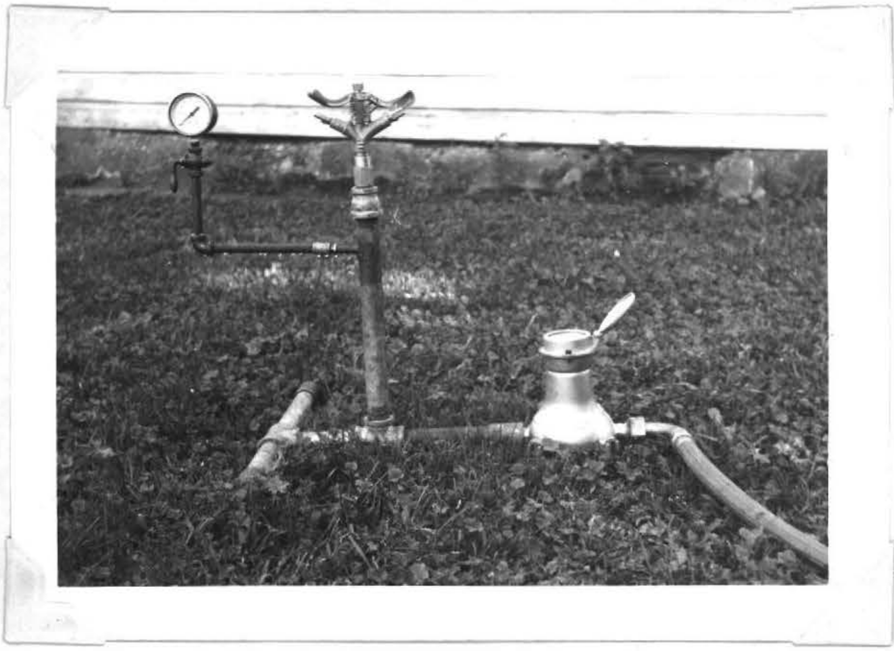

Figure 3. Apparatus used to check the volumetric method of measuring nozzle discharge. The flow line consists of a water meter, sprinkler riser with pressure gage attached, and sprinkler nozzles.

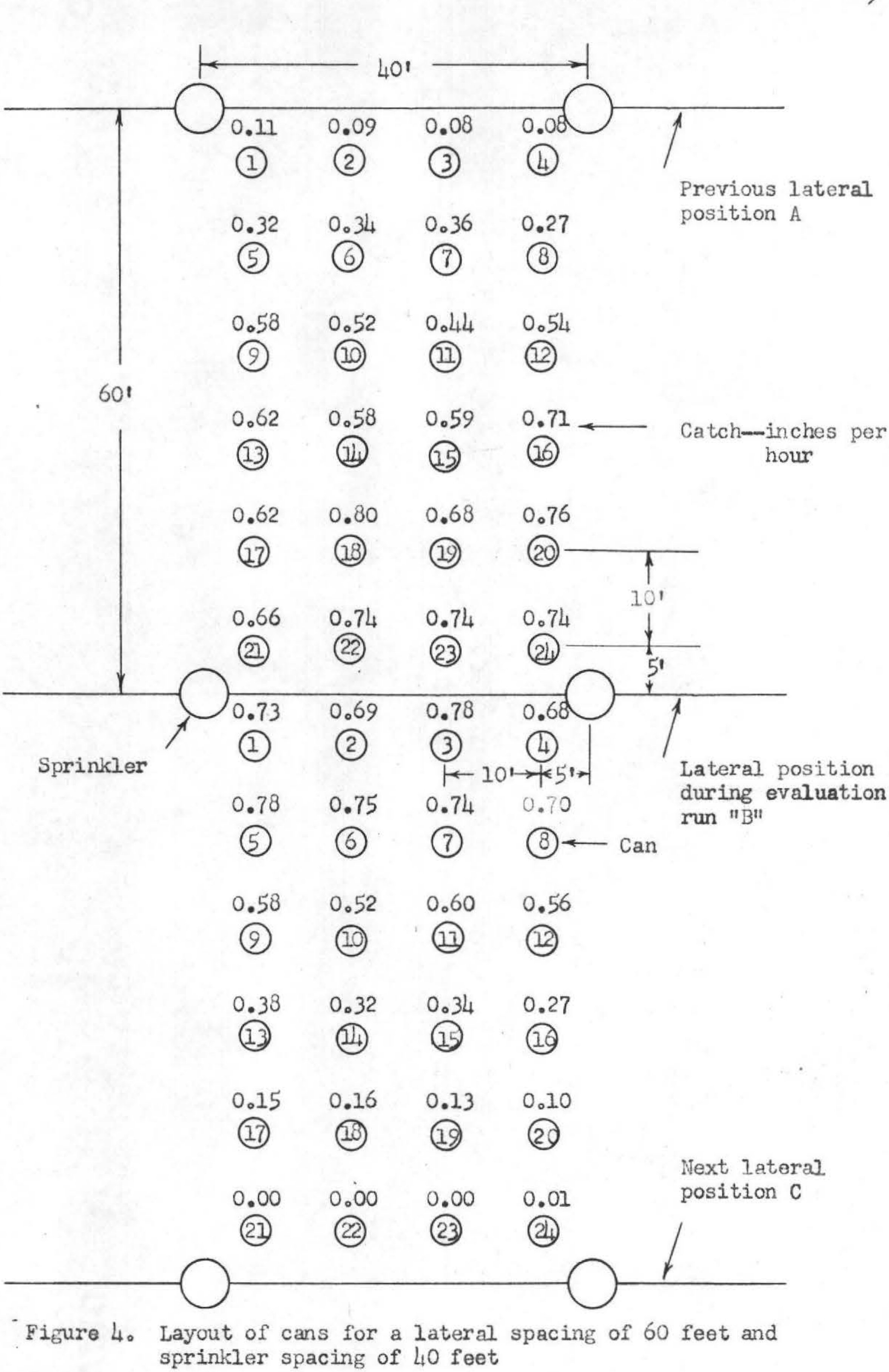

Figure 4. Layout of cans for a lateral spacing of 60 feet and sprinkler spacing of 40 feet

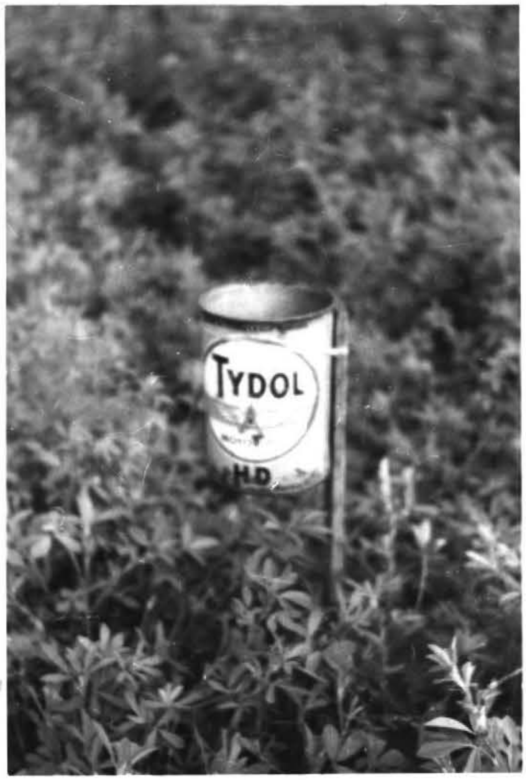

Figure 5. Can supported above crop on stake

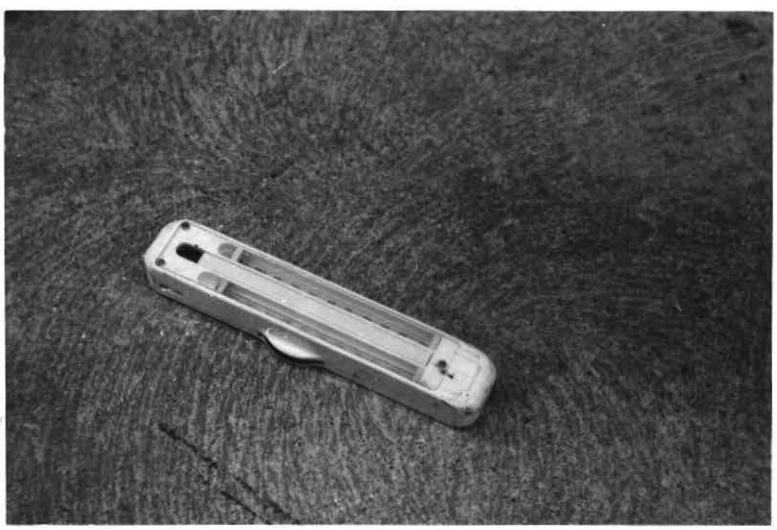

Figure 6. Hand ventilated psychrometer used to measure relative humidity

The catch in the cans was measured with a graduated cylinder. This method is much faster and more accurate than direct depth measurement with a ruler. The oil cans used hold 195.5 cubic centimeters of water per inch of depth. The graduated cylinder could be read to the nearest 5 cubic centimeters, which is equivalent to .025-inch accuracy.

The sprinklers were held at the beginning and end of each test to prevent the spray from falling into the cans while the pressure and discharge measurements were being made and while the catch in the cans was being measured.

Temperature. The temperature was measured at the beginning and end of each test and was read to the nearest degree Fahrenheit.

Humidity. The humidity was measured at the beginning and end of each test and was read to the nearest percent. A hand turbine ventilated psychrometer was used (figure 6).

Soil samples. The soil was classified to a depth of 5 feet and the water holding capacity estimated by sight and feel. The soil was classified as light, medium, or heavy. It was estimated as having an available water holding capacity of .75 to 1.0 inch per foot of sandy soil and 2.0 inches per foot for both medium and heavy textured soil.

Method of analysis

Distribution efficiency. This is calculated from the average minimum and the average catch in the cans.

The distribution efficiency is based on the total application on the test area, since the catch in the cans was obtained from one lateral setting (figure 4), it is adjusted to show the theoretical application from adjacent lateral settings. Referring to figures 4 and 7, this is done by adding together the catch from the cans with the same number. This method of obtaining the total application assumes that the

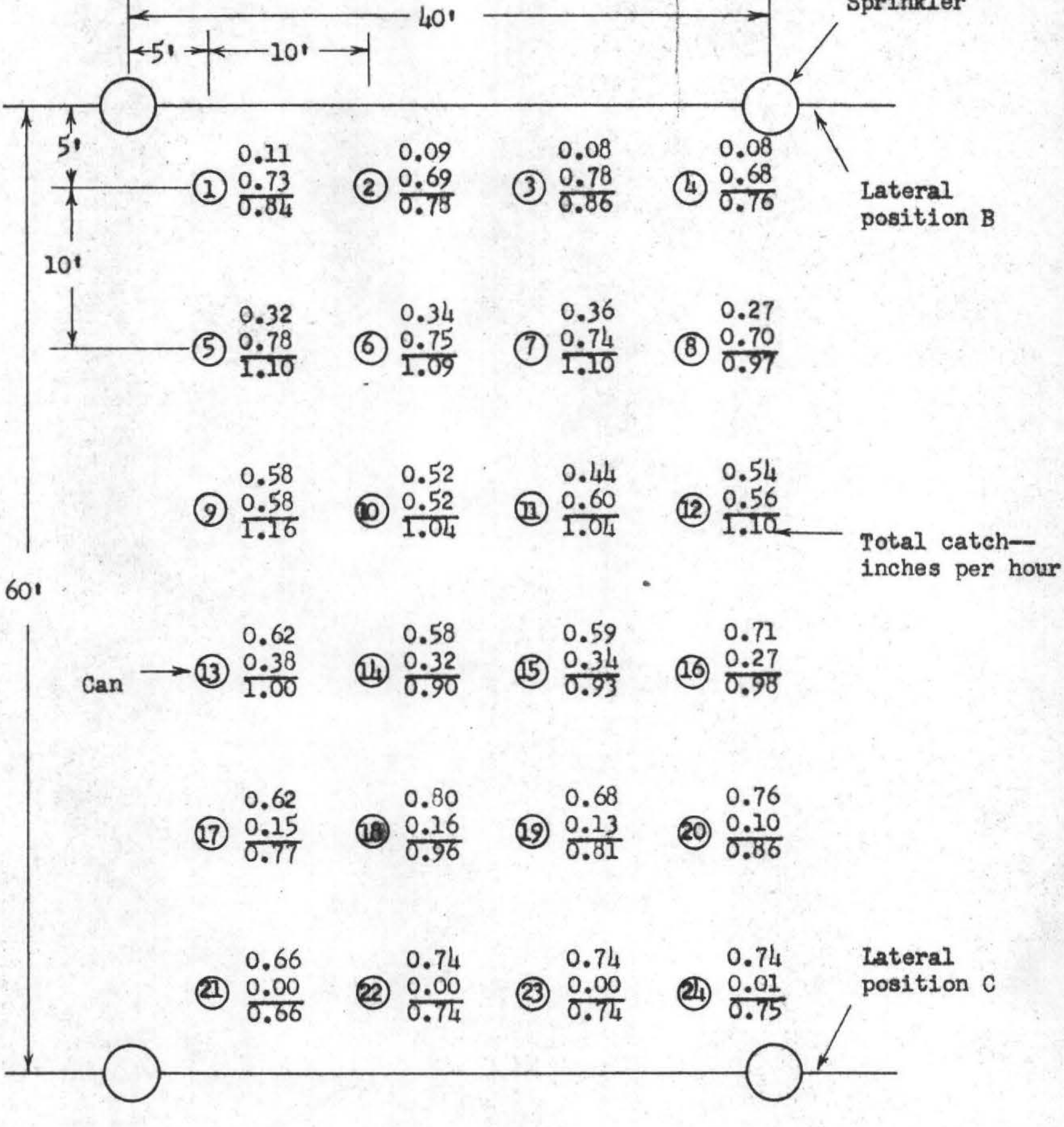

Figure 7. Method used in superimposing the catch from 1 lateral line to show the application from 2 lateral lines

distribution and the application remain the same for lateral settings B and C.

A sample calculation is shown here to illustrate the calculations.

Example:

Farm number 6

Lateral spacing = 60 feet

Sprinkler spacing = 40 feet

Average catch in cans = $\frac{\text{total catch in inches}}{\text{Number of cans}}$ =

$$\frac{21.84}{24} = 0.91 \text{ inches}$$

Average minimum catch =

$$\underline{\text{total catch in minimum 25 percent of cans in inches}} =$$

$$\frac{4.42}{6} = 0.74 \text{ inches}$$

Distribution efficiency = $\frac{\text{average minimum catch}}{\text{average catch}} \times 100$ =

$$\frac{0.74}{0.91} \times 100 = 81.4 \text{ percent}$$

The complete data for all these tests are presented in table 1.

__Water loss__. The total water loss is calculated from the average discharge from the sprinklers adjacent to the test area and the average catch in the cans.

Example:

Farm number 6

Average depth applied in test section = $\frac{96.4 \times T \times Q}{S \times L}$ = inches

where 96.4 = conversion factor

T = time in hours

Q = gallons per minute

S = sprinkler spacing in feet

L = lateral spacing in feet

Average depth applied in test area = $\frac{96.4 \times 1 \times 23.75}{40 \times 60} = 0.96$ inches

Average catch in cans = 0.91 inches

Water loss = $\frac{0.96 - 0.91 \times 100}{0.96} = 5$ percent

The complete data for all of these tests are presented in table 1.

Application efficiency. The application efficiency is dependent on the distribution efficiency and the water loss. It is calculated from the average minimum catch and the average discharge from the sprinklers adjacent to the test area.

Example:

Farm number 6

Average minimum catch = 0.74 inches

Average depth applied in test area = 0.96 inches

Application efficiency = $\frac{\text{average minimum catch}}{\text{average depth applied in test area}} \times 100 =$

$\frac{0.74}{0.96} \times 100 = 77$ percent

The complete data for all of these tests are presented in table 1.

Lateral distribution. Distribution of water along the lateral depends on the discharge from the first to last sprinkler along the line. A drop of 10 percent has become a standard figure for allowable decrease in discharge, as recommended by Christiansen (2).

Example:

Farm number 6

Discharge at first sprinkler = 24.6 gallons per minute

Discharge at last sprinkler = 20.3 gallons per minute

Decrease in discharge = 24.6 - 20.3 = 4.3 gallons per minute

Decrease in discharge = $\frac{4.3}{24.6} \times 100 = 17.5$ percent

The complete data for all of these tests are presented in table 2.

Labor costs. The total acre-inches of water applied by the sprinkler system each set was calculated from the average sprinkler discharge, the number of sprinklers, and the length of set. The man-hours required to move the pipe was obtained from the farmer.

Example:

Farm number 6

Discharge at first sprinkler = 24.6 gallons per minute

Discharge at last sprinkler = 20.3 gallons per minute

Average sprinkler discharge = $Q_1 - 3/4 \times (Q_1 - Q_2)$

where Q_1 = discharge at first sprinkler in gallons per minute

Q_2 = discharge at last sprinkler in gallons per minute

This empirical formula was developed by Christiansen (2).

Average sprinkler discharge = $24.6 - .75 \times (24.6 - 20.3) =$ 21.4 gallons per minute

Number of sprinklers on lateral = 26

Total discharge = $26 \times 21.4 = 556$ gallons per minute

Length of set used = 4 hours

Total application = $\frac{556}{450} \times 4 = 4.96$ acre-inches

Labor required to move pipe = 1 man-hour

Labor requirement = $\frac{1}{4.96} = 0.20$ man-hours per acre-inch

The complete data for labor evaluation is presented in table 3.

Minimum frequency and length of set. The length of set required to fill the root zone depends on the application rate and the available water holding capacity of the soil. The application rate was obtained by finding the average sprinkler discharge and using an application efficiency of 70 percent. The length of set required is equal to the readily available water holding capacity of the root zone divided by the application rate.

The minimum frequency depends on the readily available water-holding capacity of the root zone and the peak rate at which water is used by the crop. In calculating the minimum frequency obtainable, it was assumed that the system operated 24 hours per day and that the root zone was filled.

The root zones and peak consumptive use rates used in this report are listed below. The peak consumptive use rates were obtained from a nomograph prepared by Criddle (3).

Crop	Soil	Root zone (feet)	Available water holding capacity (inches)	Peak daily consumptive use (inches)
Alfalfa	Medium & heavy	5.0	10.0	.20
	Light	5.0	5.0	.24
Grain	Medium & heavy	3.0	6.0	.20
	Light	3.0	3.0	.24
Sugar beets	Medium & heavy	3.5	7.0	.18
	Light	3.5	3.5	.22
Peas	Medium & heavy	3.0	6.0	.19
	Light	3.0	3.0	.22
Corn	Medium & heavy	3.5	7.0	.20
	Light	3.5	3.5	.23
Pasture	Medium & heavy	3.0	6.0	.20
	Light	3.0	3.0	.24
Tomatoes	Medium & heavy	3.5	7.0	.20
	Light	3.5	3.5	.23

Nursery trees	Medium & heavy	3.0	6.0	.20
	Light	3.0	3.0	.24
Potatoes	Medium & heavy	3.5	7.0	.18
	Light	3.5	3.5	.21

A sample calculation is shown here to illustrate the procedure used in obtaining the length of set required and the minimum frequency.

Example:

Farm number 6

Crop	Area (acres)	Soil	Root zone (feet)	Readily available moisture (inches)	Peak consumptive use (inches)
Grain	60	Heavy	3	4.50	.20
Alfalfa	40	Heavy	5	7.50	.20

Average sprinkler discharge = 21.4 gallons per minute

Average application = $\frac{96.4 \times 1 \times 21.4}{40 \times 60} \times 0.70 = 0.60$ inches per hour

Length of set required--grain = $\frac{4.50}{0.60} = 7$ hours

alfalfa = $\frac{7.50}{0.60} = 12$ hours

Minimum frequency required--grain = $\frac{4.50}{0.20} = 22$ days

alfalfa = $\frac{7.50}{0.20} = 37$ days

Number of sets required to cover field--grain = 40

alfalfa = 26

Number of sets per 24-hour day--grain = $\frac{24}{8} = 3$

alfalfa = $\frac{24}{13} = 1.8$

Minimum frequency obtainable

$$= \frac{40}{3} + \frac{26}{1.8} = 27 \text{ days}$$

The complete data for these tests is presented in table 4.

Summary of results

Distribution efficiency

Distribution efficiency percent	Number of tests	Percent of tests
90–100	0	0
80–90	11	32.4
70–80	14	41.2
60–70	3	8.7
50–60	4	11.8
Less than 50	2	5.9
Total	34	100.0

The average distribution efficiency, excluding those below 70 percent, is 79.2 percent.

Water losses

Water losses percent	Number of tests	Percent of tests
0–10	16	47.05
10–20	16	47.05
20–25	2	5.9
Total	34	100.0

Average = 11.4 percent

Application efficiency

Application efficiency percent	Number of tests	Percent of tests
80–90	0	0
70–80	15	44.1
60–70	10	29.4
50–60	5	14.7
40–50	2	5.9
Less than 40	2	5.9
Total	34	100.0

The average application efficiency, excluding those that were influenced by a distribution efficiency below 70 percent, is 70.2 percent.

Line distribution

Decrease in pressure between first and last sprinkler, percent	Number of tests	Percent of tests
Less than 10	23	67.5
Greater than 10	11	32.5
Total	34	100.0

Labor costs

Man hours per acre-inch applied	Number of systems	Percent of systems
0 - .25	6	18.2
.25 - .50	15	45.5
.50 - .75	3	9.1
.75 - 1.00	8	24.2
1.00 - 1.25	1	3.0
Total	33	100.0

Average labor requirement = .50 man-hours per acre-inch.

Length of set

Length of set sufficient to fill root zone to capacity	Number of systems	Percent of systems
Yes	2	6.5
No	29	93.5
Total	31	100.0

Minimum frequency

System able to meet minimum frequency	Number of systems	Percent of systems
Yes	11	34.4
Within 7 days	8	25.0
No	13	40.6
Total	32	100.0

DISCUSSION OF RESULTS

Distribution efficiency

The distribution efficiency is affected by four factors—wind, nozzle pressure, spacing of sprinklers and lateral lines, and the operational performance of the sprinklers.

Wind has a marked effect on distribution, with the spray being blown in a distorted pattern. The greater the velocity of the wind the more pronounced is the distortion. The adverse effect of wind on distribution efficiency can be reduced by decreasing the lateral spacing. Using farm number 2 as an example, if the lateral spacing was reduced from 60 feet to 50 feet, the distribution efficiency would increase from 60 to 66 percent.

Pressure affects the distribution pattern by changing the size of the water drops. Sprinkler manufacturers recommend a pressure for each nozzle combination. This recommended pressure will result in the best distribution pattern. If the pressure is appreciably greater than the recommended, the water jet is broken into fine drops and a large portion of the water falls near the nozzle. The circle of coverage is reduced and wind has a more pronounced effect on the distribution because of the fine drops. Excess pressure was not a problem with the systems studied.

If the pressure is appreciably less than the recommended, the water drops remain large and fall in a narrow band toward the outside of the circle of coverage. This gives a "doughnut-like" appearance to the distribution pattern and the circle of coverage is reduced.

The effect of low pressure cannot be shown graphically from the data in this study since individual nozzles were not used in the evaluations. The patterns obtained from the study are the result of four adjacent sprinklers operating simultaneously. Christiansen (2) adequately illustrates the effects of pressure on distribution patterns.

The effect of low operating pressures with the systems studies is reflected in the distribution efficiencies.

Spacing of lateral lines was briefly discussed with wind. It was illustrated how the distribution efficiency can be increased by reducing the spacing.

To accurately determine the effect of the various factors, it would be necessary to have all of the factors under control so that they could be varied as desired. Such was not possible in this study. The tests were run with the conditions that existed on each system in the field.

Of the 6 tests that were run with a wind of greater than 5 miles per hour, all had a distribution efficiency below 70 percent. These results indicate that where wind in excess of 5 miles per hour is present during much of the irrigation season, greater care must be taken in designing the system, giving special attention to sprinkler and lateral spacing.

The remaining 28 tests were run with only a slight wind or no wind. Of these, 3 had distribution efficiencies below 70 percent; the reason for each one being low can be attributed to an extreme condition of at least one of the afore mentioned factors.

For instance, with farm number 1, the manufacturers' recommended operating pressure is 40 pounds per square inch. The pressure used was only 15 pounds per square inch. Also, the largest recommended lateral spacing is 51.5 feet, and a spacing of 60 feet was used.

With farm number 25, the recommended lateral spacing is 55.5 feet but 80-foot spacing was used. If a 60-foot lateral spacing had been used, the distribution efficiency would have increased from 64 to 87 percent.

Farm number 31 sprinkler system was not operating properly. The speed of rotation of the sprinklers was very erratic and the sprinklers frequently stopped during the test. This test was completed to show what extremely low distribution efficiency is possible if the sprinklers are not kept in good repair.

Of the 25 tests having distribution efficiencies greater than 70 percent, 13 were between 70 and 80 percent, and 12 were between 80 and 90 percent. Since it was not possible to control the factors affecting distribution, it is difficult to explain this variance in distribution efficiency. In some instances the factors counterbalance one another. However, some significant observations were made.

The wind was less than 5 miles per hour for the entire 25 tests. A wind of 5 miles per hour is believed to have a definite effect on distribution when compared to conditions of no wind. However, of 11 tests run with slight wind conditions, 6 fell in the 70 and 80 percent range and 5 fell in the 80 to 90 percent range.

Of the 12 tests having efficiencies of 80 to 90 percent, 8 systems were operating within 20 percent of the design pressure. The other 4 operated at pressures below 80 percent of the design pressure. It is interesting to note that all 4 of these systems used either lateral spacing or sprinkler spacing 10 feet less than that recommended. All of the 12 systems used lateral spacing equal to or less than recommended.

Of the 13 systems having efficiencies of 70 to 80 percent, only 5 were operating within 20 percent of the design pressure. Of the remaining 8 systems, only 1 used a lateral spacing less than recommended.

Three of the systems having efficiencies between 70 and 80 percent were tested under what is believed to be ideal conditions; that is, there was no wind, lateral spacing was equal to or less than recommended, and the operating pressures were within 20 percent of the design pressure. There is nothing in the data to explain why these efficiencies should not have been higher. A factor which would not appear in the data but which could reduce the efficiency is the evenness of rotation of the nozzles. In some tests, nozzle rotation may have been sufficiently erratic to cause a distortion of the pattern.

From these results, it would appear that, in most cases, if the operating pressure is within 20 percent of the design pressure, and the lateral spacing is not greater than that recommended, a distribution efficiency of 80 percent is readily obtainable.

The recommended nozzle pressures and lateral spacing used herein were obtained from National Rain Bird Sales and Engineering Corporation, Catalog 17.

The summary of the data for these tests is presented in table 5.

Water losses

The average water losses, as determined by these tests, was .05 inch per hour. There was no apparent relationship between the loss and the rate of application. Thus, the percent of water loss increases as the application rate decreases. Water loss as determined from the measured catch in the cans includes the loss by evaporation from the spray, evaporation from the cans during the test, plus the film of water which clings to the can when emptied.

Christiansen (2) ran tests to determine the loss that could be attributed to water clinging to the cans and concluded that this loss was about 1 cubic centimeter or 3 percent of the average amount caught. This would make the average catch in the cans 33.3 cubic centimeters in his tests. All of the average catchs obtained in the tests reported here were larger than this. Since the graduate used to measure the catch was read to the nearest 5 cubic centimeters, this loss is insignificant.

Two curves (figure 8 and 9) were drawn to attempt to correlate the water losses with temperature and humidity. Figure 8 shows water loss in inches per hour plotted against temperature in degrees Fahrenheit. Figure 9 shows the variation in water loss, either plus or minus, which was obtained from the water loss-temperature curve, against relative humidity. Both curves were drawn using the method of least squares.

These curves indicate that the water loss is dependent on both temperature and relative humidity. The water loss increases as the temperature increases and the relative humidity decreases.

For an average temperature of 75 degrees Fahrenheit, which is approximately the average for July in the area studied, and an average relative humidity of 40 percent, the average water loss was .06 inches per hour. The loss would require an application rate of 0.6 inch per hour to keep the loss to 10 percent of the application.

The maximum loss in percent found in these tests was 22.

Six of the tests were run with wind conditions of greater than 5 miles per hour. The losses from 3 of these tests were at least .02 inches per hour greater than the average as determined from figure 8. The other 3 tests varied less than .01 inch per hour from the average. Since only 6 tests were completed under wind conditions that were only

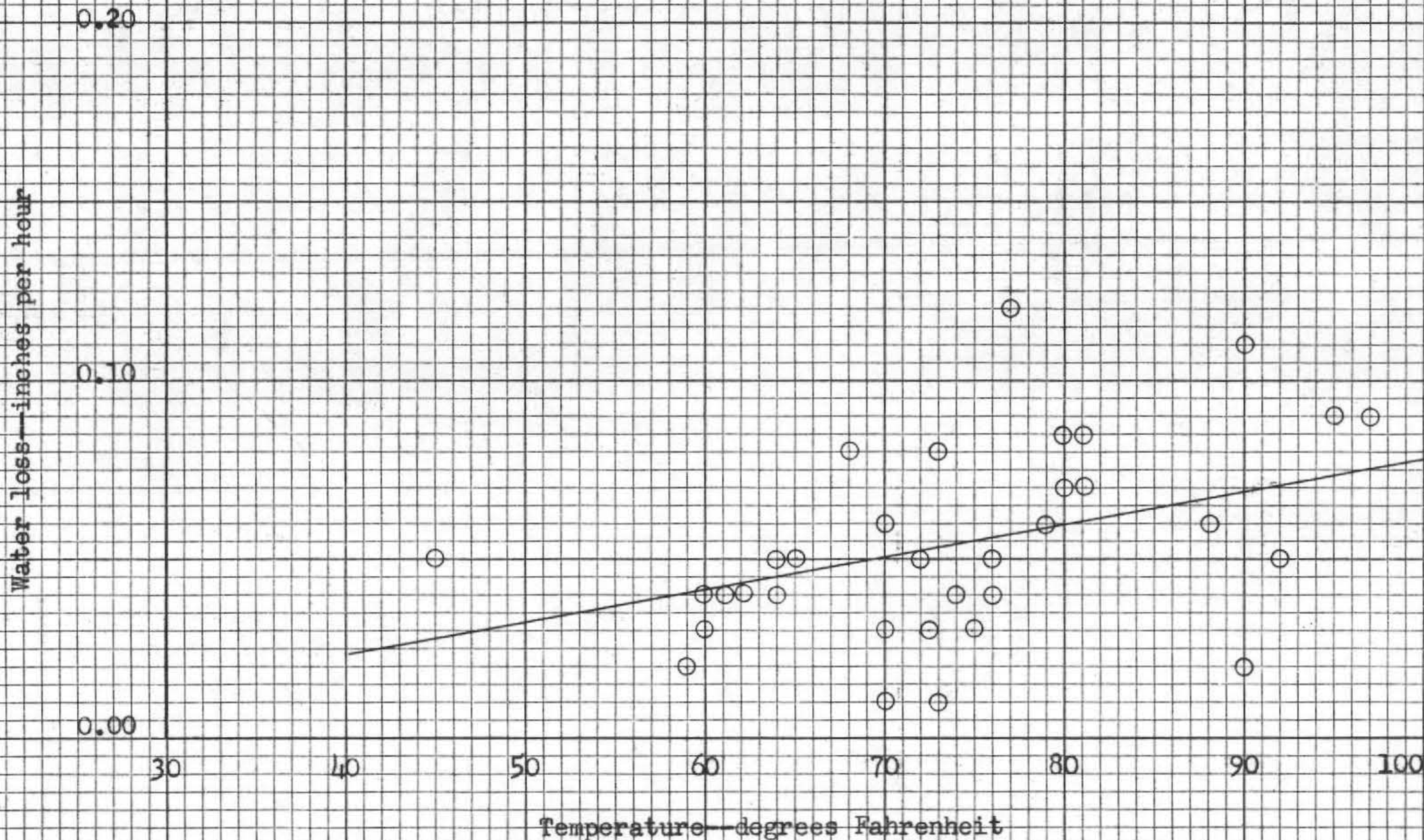

Figure 8. Variation of water loss from sprinkler irrigation with temperature for northern Utah sprinkler evaluation studies in 1954

Note: This graph must be used in conjuction with figure 8, to determine water loss with any given temperature and relative humidity.

Example: Temperature = 70° F.
Relative humidity = 30 percent

From figure 8
Water loss at 70° F. = .05 inches per hour

From figure 9
Variation in water loss at 30 percent relative humidity = plus .03 inches per hour

Total water loss = .05 + .03 = .08 inches per hour

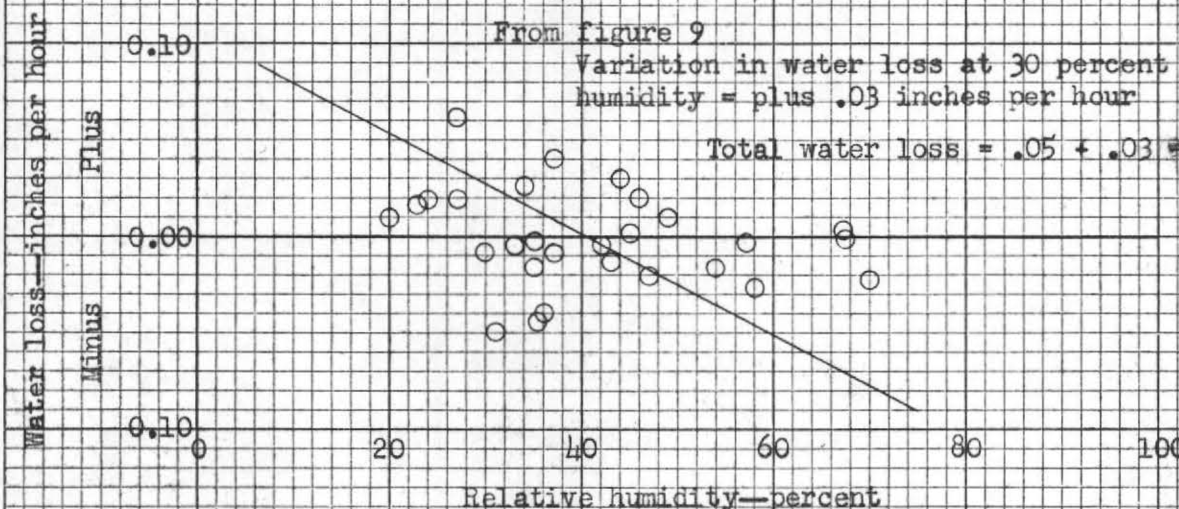

Figure 9. Influence of relative humidity on water loss from sprinkler irrigation systems in northern Utah in 1954

estimated, it is difficult to determine the relationship that wind had on water losses.

Application efficiency

The application efficiency as thus defined depends on the distribution efficiency and the water losses.

Nine of the tests had an efficiency below 60 percent; 8 of these can be attributed to distribution efficiencies below 20 percent, and one to a large water loss of 21 percent.

It is evident from these results that it is desirable to increase the distribution efficiency as much as possible. Inasmuch as the water losses are not controllable, the only way to increase the application efficiency is to improve the distribution efficiency.

Lateral efficiency

Of the 34 tests completed, 11 had a nozzle discharge drop along the line of greater than 10 percent.

This excessive drop in discharge is caused by using pipe that is too small and has high friction losses or there may have been a change in elevation.

This reflects poor design or an attempt on the part of the farmer to reduce initial costs at the expense of good distribution of water along the line.

Labor requirements

The average labor cost of .50 man-hours per acre-inch is generally lower than has been reported in the literature. This indicates that labor requirements for sprinkler irrigation in northern Utah are favorable.

Interviews with the farmers revealed that 10 thought labor requirements were the same for sprinkling and flood irrigation, 10 thought sprinkling required less labor, 7 thought labor for sprinkling was more, and 6 gave no comparison as the land had not been previously irrigated.

None of the farmers interviewed hired labor specifically to move and operate the sprinkling system. Usually the operation of the system was integrated into the farm work without too much apparent difficulty or inconvenience.

System efficiency and operation

The ability of the system to adequately irrigate the crops and meet the minimum frequency is very important.

Of the 33 systems on which operational procedure was obtained, two used the system only to irrigate the crops up. These are not included in the analysis. One of the farms is reported twice, since 30 acres was served by continuous delivery and was able to meet the minimum frequency. Another 30 acres was served by rotation delivery, which was unable to meet the minimum frequency. This makes a total of 32 farms included in the analysis.

The data presented in the report shows that the operation and system efficiency of the systems checked is generally poor, with only 11 of 32 systems having a capacity large enough to meet the minimum frequency. Of these 11 systems, only 2 were operated so that enough water was applied to fill the root zone each irrigation.

The length of set required for farms 4, 8, 13, and 16 will be somewhat less than shown in the analysis because some water was supplied to the root zone by a high water table. The minimum frequency obtainable of these systems would therefore also be less.

Of the 13 systems that could not meet the minimum frequency, 4 received water under the rotation system of delivery. One of these 4 systems, farm number 14, would have been able to meet the minimum frequency with continuous delivery. The remaining 3 would not have been able to meet the minimum frequency with continuous delivery, but the irrigation interval in each case would be substantially decreased.

The disadvantage of not meeting these two requirements is great. Although yield data was not obtained, it is reasonable to assume that they would be greatly decreased with such inadequate irrigation. Applications that do not fill the root zone increase the number of irrigations needed each year, which increases the labor costs. Evaporation from the soil takes place largely from the first foot, thus evaporation losses are about the same for all irrigations that supply water enough to at least fill the first foot. Evaporation from the soil may be as high as 1 inch between irrigations. If only light applications are made, this represents a large water loss.

CONCLUSIONS

The objectives stated at the beginning of the study have been realized, and the following conclusions, concerning these objectives, arrived at:

1. It is possible to obtain an average distribution efficiency of 80 percent if the nozzle pressure and the lateral spacing are properly designed and the sprinklers kept in good repair. If strong winds are a constant factor, special attention should be given lateral spacing.

2. The water losses will seldom be more than 0.1 inches per hour, with the average for July being approximately .06 inches per hour.

3. The average application efficiency as found by these tests was 70 percent.

The water losses are largely uncontrollable, but the distribution is not. If care is taken to insure a high distribution efficiency, the application efficiency will correspondingly increase. If care is taken to insure high distribution efficiency, an average application of 70 percent is readily obtainable.

4. Greater care must be taken by the designer to prevent poor lateral distribution. The fact that 32.5 percent of the systems checked had discharge drop along the lateral of greater than 10 percent emphasizes this.

5. Labor costs are not a disadvantage of sprinkling in northern Utah.

6. The general design and operation of the systems checked were generally poor. Only 2 of the 32 systems applied enough water to fill

the root zone each irrigation and were able to meet the minimum frequency requirements. This is an important aspect of good irrigation practice and everyone concerned with sprinkler irrigation should try to improve the present conditions.

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Table 1. Irrigation evaluation data for 1954, including distribution and application efficiencies and water losses of sprinkler systems in northern Utah

Farm number	Date—1954	Time--24-hour clock	Length of test--hours	Average temperature--degrees F.	Average relative humidity--percent	Nozzle pressure in test section--p.s.i.	Discharge from nozzles in test section--g.p.m.	Average depth applied to test area--inches	Average catch in cans--inches	Catch in minimum 25 percent of cans--inches	Distribution efficiency--percent	Water application efficiency--percent	Water losses--percent
1	3 June	0930 1230	3.0	72.5		15.0	7.4	0.30	0.27	0.18	66	60	9
2	7 June	1505 1705	2.0	65.0		30.0	11.0	0.44	0.39	0.24	60	55	11
3	7 June	1100 1400	3.0	60.0		44.0	19.5	0.42	0.38	0.22	58	53	9
4	8 June	1010 1220	2.17	45.0		40.0	9.2	0.37	0.32	0.17	51	45	13
5	10 June	1300 1600	3.0	70.0		37.5	9.8	0.40	0.34	0.26	77	65	15
6	11 June	1105 1335	2.5	72.0	35.0	28.5	23.7	0.96	0.91	0.74	81	77	5
7	15 June	1440 1940	5.0	73.0	36.0	23.5	5.3	0.21	0.21	0.15	71	70	2
8	15 June	0945 1245	3.0	68.0	44.0	28.0	14.5	0.58	0.50	0.43	86	74	13
9	16 June	1010 1310	3.0	61.0	70.0	32.5	8.7	0.35	0.33	0.24	73	69	6
10	17 June	1030 1330	3.0	64.0	42.0	25.0	8.3	0.45	0.40	0.35	86	78	9
11	18 June	1440 1640	2.0	77.0	27.0	38.0	15.1	0.73	0.61	0.50	82	69	16
12	18 June	0745 1045	3.0	60.5	43.0	26.0	10.5	0.42	0.39	0.30	76	70	7
13	23 June	1340 1540	2.0	97.0	26.0	38.0	15.8	0.63	0.54	0.46	85	73	14
14	24 June	1020 1120	1.0	74.0	54.0	33.0	37.5	1.51	1.44	1.12	78	8	5

Table 1. (Continued)

Farm number	Date--1954	Time--24-hour clock	Length of test--hours	Average temperature --degrees F.	Average relative humidity--percent	Nozzle pressure in test section--p.s.i.	Discharge from nozzles in test section--g.p.m.	Average depth applied to test area--inches	Average catch in cans--inches	Catch in minimum 25 percent of cans --inches	Distribution efficiency--percent	Water application efficiency--percent	Water losses--percent
15	24 June	1520 1720	2.0	88.5	37.0	32.0	11.1	0.45	0.41	0.34	83	75	9
16	26 June	0755 0955	2.0	80.5	49.0	25.0	12.9	0.52	0.45	0.33	73	63	15
17	26 June	0550 0650	1.0	70.0	47.0	40.0	6.9	0.28	0.25	0.15	60	53	10
18	29 June	0910 1140	2.5	74.0	34.0	30.0	15.3	0.61	0.54	0.41	76	67	13
19	30 June	0950 1150	2.0	76.0	35.0	27.0	11.5	0.46	0.42	0.33	79	73	8
20	30 June	0535 0805	2.5	62.0	67.0	42.0	9.1	0.37	0.34	0.33	70	63	10
21	6 July	0810 1110	3.0	79.0	45.0	33.0	6.5	0.26	0.23	0.21	88	79	10
22	8 July	0508 0725	2.3	63.5	57.0	45.0	12.4	0.50	0.45	0.38	84	76	10
23	9 July	1125 1355	2.5	90.0	37.0	38.0	21.3	0.64	0.53	0.17	32	27	17
24	10 July	0600 0800	2.0	67.0	57.0	38.0	11.5	0.46	0.42	0.32	76	69	9
25	12 July	1015 1215	2.0	92.5	33.5	36.5	7.2	0.22	0.18	0.11	63	51	19
26	13 July	0825 1025	2.0	82.0	46.0	34.0	15.0	0.60	0.52	0.43	84	72	14
27	14 July	1250 1350	1.0	95.0	23.0	31.0	8.2	0.65	0.56	0.30	54	46	14

Table 1. (Continued)

Farm number	Date--1954	Time--24-hour clock	Length of test--hours	Average temperature--degrees F.	Average relative humidity--percent	Nozzle pressure in test section--p.s.i.	Discharge from nozzles in test section--g.p.m.	Average depth applied to test area--inches	Average catch in cans--inches	Catch in minimum 25 percent of cans--inches	Distribution efficiency--percent	Water application efficiency--percent	Water losses--percent
28	14 July	0900 1100	2.0	90.0	31.0	22.0	11.5	0.51	0.49	0.37	75	73	4
29	23 July	0655 0855	2.0	70.5	36.5	38.0	6.7	0.27	0.26	0.19	73	70	4
30	28 July	1000 1235	2.58	81.5	19.5	32.0	8.0	0.32	0.25	0.21	84	67	22
31	28 July	0735 0935	2.0	75.5	58.5	24.5	10.2	0.41	0.34	0.02	6	5	17
32	30 July	0855 1105	2.17	80.0	27.0	40.0	9.5	0.38	0.30	0.22	73	58	21
33	31 July	0830 1030	2.0	76.5	30.0	36.0	8.5	0.41	0.36	0.30	83	73	12
34	3 Aug.	0950 1150	2.0	80.5	24.0	29.5	8.5	0.51	0.43	0.34	80	66	17

Table 2. Lateral distribution data of sprinkler systems in northern Utah for 1954

Farm number	Line number	Pressure at first nozzle --p.s.i.	Pressure at last nozzle--p.s.i.	Loss in pressure --p.s.i.	Loss in pressure --percent	Discharge at first nozzle--g.p.m.	Discharge at last nozzle--g.p.m.	Loss in discharge --g.p.m.	Loss in discharge --percent
1	1	15	26	+11	+42.0	7.6	9.4	+1.8	+19.2
	2	16	23	+ 7	+30.0	7.3	9.1	+1.8	+19.8
	3	16	23	+ 7	+30.0	7.4	8.7	+1.3	+15.0
2	1	34	30	4	11.8	10.9	9.8	1.1	10.1
3	1	47	43	4	8.5	20.1	18.9	1.2	6.0
	2	52	44	8	15.4	21.0	19.4	1.6	7.6
	3	54	46	8	14.8	22.2	19.6	2.6	11.7
4	1	40	38	2	5.0	9.1	8.9	0.2	2.2
5	1	56	27	29	51.8	10.6	8.3	2.3	21.5
6	1	30	22	8	26.7	24.6	20.3	4.3	17.5
7	1	29	27	2	6.9	6.1	6.0	0.1	1.6
8	1	33	22	11	33.3	15.0	15.0	0.0	0.0
9	1	37	32	5	13.5	9.3	8.5	0.8	8.4
10	1	28	29	+ 1	+ 3.5	8.4	8.8	+0.4	+ 4.5
11	1	41	37	4	9.8	15.9	15.0	0.9	5.7
	2	41	37	4	9.8	15.8	15.1	0.7	4.4
	3	41	37	4	9.8	15.9	15.1	0.8	5.0
12	1	30	24	6	20.0	10.4	10.2	0.2	1.9
	2	29	26	3	10.3	10.8	9.2	1.6	14.8
13	1	42	38	4	9.5	16.1	15.8	0.3	2.0
	2	44	42	2	4.5	17.1	16.0	1.1	6.5
14	1	33	32	1	3.0	38.7	36.3	2.4	6.2
15	1	42	30	12	28.6	12.2	10.9	1.3	10.7
	2	40	40	0	0	12.4	12.4	0	0

Note: + indicates a gain

Table 2. (Continued)

Farm number	Line number	Pressure at first nozzle—p.s.i.	Pressure at last nozzle—p.s.i.	Loss in pressure —p.s.i.	Loss in pressure —percent	Discharge at first nozzle—g.p.m.	Discharge at last nozzle—g.p.m.	Loss in discharge —g.p.m.	Loss in discharge —percent
16	1	30	25	5	16.7	14.0	12.8	1.2	8.6
17	1	42	36	6	14.3	7.3	6.5	0.8	11.0
18	1	32	19	13	40.6	18.0	14.6	3.4	18.8
19	1	38	26	12	31.6	13.7	11.2	2.5	18.2
	2	34	26	8	23.5	13.1	10.4	2.7	20.6
20	1	42	41	1	2.4	9.2	9.1	0.1	0.2
21	1	38	33	5	13.2	7.0	6.7	0.3	5.0
22	1	45	43	2	4.4	12.2	12.0	0.2	1.6
	2	45	44	1	2.2	12.5	12.0	0.5	4.0
23	1	42	37	5	12.0	23.6	21.2	2.4	10.1
24	1	40	36	4	10.0	11.5	11.0	0.5	4.3
	2	40	38	2	5.0	11.5	11.2	0.3	2.6
25	1	49	17	32	65.2	7.4	5.0	2.4	32.4
26	1	40	31	9	22.5	16.2	14.3	1.9	11.7
27	1	36	33	3	8.3	8.6	8.1	0.5	5.8
28	1	22	22	0	0.0	12.1	12.1	0.0	0.0
	2	21	20	1	4.8	11.5	11.2	0.3	2.6
29	1	37	36	0	0.0	6.8	6.8	0.0	0.0
	2	36	36	0	0.0	6.8	6.6	0.2	3.0
	3	36	36	1	3.0	6.8	6.5	0.3	4.4
30	1	38	30	8	21.0	8.8	8.3	0.5	5.7
31	1	24	25	+ 1	+ 4.2	10.2	11.9	+ 1.7	+16.5
	2	23	23	0	0.0	9.8	9.8	0.0	0.0
32	1	41	36	5	12.2	9.2	8.8	0.4	4.4
33	1	40	32	8	20.0	9.2	8.2	1.0	10.9
34	1	32	28	4	12.5	9.0	8.5	0.5	5.6

Table 3. Labor cost data of sprinkler systems in northern Utah for 1954

Farm number	Spacing of lateral --feet	Length of lateral --feet	Area covered each set--acres	Average application --g.p.m.	Average application --acre-inches per hour	Duration of application--hours	Total application --acre-inches	Average depth of application--inches	Time required to move lateral--man-hours	Time per acre-inch of application--man-hours
1	60	2600	3.58	509	1.1	10.0	11.3	3.2	3.0	0.27
2	60	920	1.27	232	0.5	2.0	1.0	0.8	0.5	0.49
3	75	2160	3.72	713	1.6	11.0	17.4	4.7	2.0	0.11
4	60	880	1.21	196	0.4	2.0	0.9	0.7	1.0	1.15
5	60	1800	2.48	400	0.9	10.0	8.9	3.6	2.0	0.22
6	60	1040	1.43	556	1.2	4.0	5.0	3.5	1.0	0.20
8	60	1520	2.09	570	1.3	4.0	5.1	2.4	2.0	0.39
9	60	960	1.32	209	0.5	3.5	1.6	1.2	1.5	0.92
10	60	720	0.99	213	0.5	6.0	2.8	2.8	1.0	0.36
11	60	1080	1.49	413	0.9	2.5	2.3	1.5	1.0	0.43
12	60	2000	2.76	493	1.1	11.0	12.1	4.4	1.0	0.08
13	60	800	1.10	322	0.7	6.0	4.3	3.9	2.0	0.47
14	80	510	0.94	613	1.4	1.3	1.8	1.3	1.3	0.72
15	40	1520	1.40	438	1.0	8.0	7.7	5.5	4.0	0.52
16	60	1240	1.71	406	0.9	4.0	3.6	2.1	1.0	0.28
17	60	1360	1.87	227	0.5	5.0	2.5	1.3	1.0	0.40
18	60	1040	1.43	403	0.9	2.0	1.8	1.3	1.5	0.84
19	60	1280	1.76	372	0.8	11.0	9.1	5.2	1.5	0.16
20	60	760	1.05	174	0.4	3.0	1.2	1.1	1.0	0.86
21	60	1320	1.82	222	0.5	5.0	2.4	1.3	1.0	0.41
22	60	1080	1.49	327	0.7	5.0	3.6	2.4	1.0	0.27
23	80	720	1.32	392	0.9	1.5	1.3	1.0	1.0	0.76
24	60	1080	1.49	302	0.7	4.0	2.7	1.8	1.7	0.65

Table 3. (Continued)

Farm number	Spacing of lateral --feet	Length of lateral --feet	Area covered each set--acres	Average application --g.p.m.	Average application --acre-inches per hour	Duration of application--hours	Total application --acre-inches	Average depth of application--inches	Time required to move lateral--man-hours	Time per acre-inch of application--man-hours
25	80	1400	2.57	196	0.4	11.0	4.8	1.9	1.5	0.31
26	60	1680	2.32	649	1.4	4.0	5.8	2.5	2.0	0.35
27	40	440	0.41	180	0.4	2.0	0.8	2.0	0.7	0.87
28	50	720	0.83	211	0.5	6.0	2.8	3.4	1.5	0.46
29	60	1560	2.14	260	0.6	6.0	3.5	1.6	3.0	0.87
30	60	1280	1.76	268	0.6	10.0	6.0	3.4	1.0	0.17
31	60	1040	1.43	265	0.6	6.0	3.5	2.4	1.0	0.28
32	60	800	1.10	178	0.4	4.0	1.6	1.5	1.5	0.95
33	50	1200	1.38	253	0.6	6.0	3.4	2.5	1.5	0.45
34	40	1000	0.92	215	0.5	8.0	3.8	4.1	3.0	0.78

Table 4. Evaluation data for sprinkler systems in northern Utah, including minimum frequency and length of set for 1954

Farm number	Area of farm--acres	Type of water delivery	Crop	Soil	Readily available water holding capacity of root zone soil--inches	Application rate--inches per hour	Length of set required--hours	Number of sets to cover field	Minimum frequency required--days	Minimum frequency obtainable--days	Length of set used--hours
1	140	Continuous	Alfalfa	Heavy	7.50	0.22	34	58	37	106	10
	40		Grain		4.50		20	17	22		
2	20	Continuous	Grain	Heavy	4.50	0.28	16	14	22	22	2
	20		Sugar beets		5.25		19	14	29		
3	50	Continuous	Sugar beets	Light	2.67	0.29	9	23	12	16	11
	20		Grain		2.25		8	9	10		
	10		Alfalfa		3.75		13	5	16		
4	20	Continuous	Peas	Heavy	4.50	0.25	18	14	24	40	2
	40		Barley		4.50		18	29	22		3
	10		Sugar beets		5.25		21	7	29		2
5	25	Continuous	Alfalfa	Heavy	7.50	0.25	30	10	37	38	10
	75		Grain		4.50		18	30	22		
6	60	Continuous	Grain	Medium	4.50	0.61	7	40	22	27	4
	40		Alfalfa		7.50		12	26	37		
8	400	Continuous	Grain	Heavy	4.50	0.42	11	147	22	73	4
9	50	Continuous	Grain	Heavy	4.50	0.24	19	36	22	78	3.5
	50		Alfalfa		7.50		31	36	37		
10	20	Continuous	Grain	Light	2.25	0.32	7	17	10	12	6
	10		Corn		2.67		8	9	12		
	10		Sugar beets		2.67		8	9	12		
11	8	Continuous	Sugar beets	Light	2.67	0.51	5	5	12	3	2.5
	2		Potatoes		2.67		5	2	13		
	6		Peas		2.25		5	3	10		

Table 4. (Continued)

Farm number	Area of farm—acres	Type of water delivery	Crop	Soil	Readily available water holding capacity of root zone soil—inches	Application rate—inches per hour	Length of set required—hours	Number of sets to cover field	Minimum frequency required—days	Minimum frequency obtainable—days	Length of set used—hours
12	140	Continuous	Alfalfa	Medium	7.50	0.29	26	50	37	56	11
13	23	Continuous	Grain	Medium	4.50	0.45	10	17	22	9	6
14	20	Rotation	Pasture	Light	2.25	1.04	2	16	9	21	1.3
	20		Alfalfa		3.75		4	16	16		
	20		Grain		2.25		2	16	10		
15	10	Continuous	Pasture	Light	2.25	0.47	5	5	9	6	8
	45		Grain		2.25		5	20	10		
16	60	Continuous	Alfalfa	Heavy	7.50	0.37	20	33	37	41	4
	40		Grain		4.50		12	22	22		
17	35	Continuous	Peas	Light	2.25	0.19	12	10	10	16	3
	45		Alfalfa		3.75		20	12	16		8
18	40	Continuous	Alfalfa	Medium	7.50	0.45	17	22	37	17	2
19	13	Continuous	Grain	Medium	4.50	0.33	14	9	22	11	11
	12		Pasture		4.50			8	22		
20	45	Continuous	Grain	Medium	4.50	0.26	17	22	22	17	3
21	35	Rotation	Alfalfa	Heavy	7.50	0.19	40	18	37	108	6
	45	Rotation	Grain		4.50		23	22	22		5
22	15	Rotation	Alfalfa	Light	3.75	0.34	11	17	16	84	5
	15		Sugar beets		2.67		8	17	12		
22	15	Continuous	Alfalfa	Light	3.75	0.34	11	17	16	15	5
	15		Sugar beets		2.67		8	17	12		

Table 4. (Continued)

Farm number	Area of farm—acres	Type of water delivery	Crop	Soil	Readily available water holding capacity of root zone soil—inches	Application rate—inches per hour	Length of set required—hours	Number of sets to cover field	Minimum frequency required—days	Minimum frequency obtainable—days	Length of set used—hours
23	25	Continuous	Alfalfa	Light	3.75	0.46	8	16	16	11	2.5
	25		Grain		2.25		5	16	10		1.5
	10		Peas		2.25		5	6	10		1.5
25	50	Continuous	Alfalfa	Light	3.75	0.12	31	25	16	56	
	50		Grain		2.25		19	25	10		
26	100	Continuous	Alfalfa	Heavy	7.50	0.44	17	30	37	22	4
28	20	Continuous	Alfalfa	Light	3.75	0.36	11	12	16	8	6
	10		Tomatoes		2.67		7	6	12		
29	14	Continuous	Nursery Trees	Heavy	4.50	0.19	24	9	22	9	6
30	100	Rotation	Alfalfa	Heavy	7.50	0.26	29	55	32	98	10
31	11	Continuous	Alfalfa	Light	3.75	0.29	13	10	16	6	6
32	30	Continuous	Alfalfa	Light	2.25	0.25	9	12	9	8	6
	20		Grain		1.87		8	8	8		4
33	80	Continuous	Alfalfa	Heavy	7.50	0.30	25	44	32	84	6
	100		Grain		4.50		15	55	22		6
34	15	Continuous	Alfalfa	Light	2.25	0.36	6	13	9	6	8
	10		Grain		1.87		5	9	8		5

Table 5. Evaluation data of sprinkler systems in western Utah, including distribution efficiencies for 1954

Farm number	Nozzle size—inches	Nozzle model*	Discharge in test section—g.p.m.	Pressure in test section—p.s.i.	Recommended design pressure—p.s.i.	Spacing of lateral—feet	Recommended spacing—feet	Wind	Percent of design pressure	Distribution efficiency—percent
1	13/64 - 5/32	40	7.4	15.0	40	60	51.5	N	37.5	66
2	13/64 - 5/32	40	11.0	30.0	40	60	58.9	W	75.0	60
3	1/4 - 3/16	70	19.5	44.0	45	75	73.5	W	97.8	58
4	3/16 - 1/8	40	9.2	40.0	35	60	57.5	W	114.0	51
5	3/16 - 1/8	40	9.8	37.5	35	60	58.8	S	107.0	77
6	5/16 - 7/32	70	23.7	28.5	55	60	72.5	S	51.9	81
7	11/64 - 3/32	40	5.3	23.5	30	60	49.8	S	78.4	71
8	7/32 - 3/16	70	14.5	28.0	45	60	69.5	S	62.3	86
9	3/16 - 1/8	40	8.7	32.5	35	60	57.0	S	92.8	73
10	13/64 - 5/32	40	8.3	25.0	40	60	51.5	N	62.5	86
11	7/32 - 3/16	40	15.1	38.0	45	60	63.0	S	84.3	82
12	13/64 - 5/32	40	10.5	26.0	40	60	57.0	N	65.0	76
13	7/32 - 3/16	70	15.8	38.0	45	60	70.0	S	84.5	85
14	3/8 - 7/32	70	37.5	33.0	55	80	76.8	N	60.0	78
15	13/64 - 5/32	40	11.1	32.0	40	40	58.8	N	80.0	83
16	7/32 - 3/16	40	12.9	25.0	45	60	57.5	S	55.5	73
17	11/64 - 3/32	40	6.9	40.0	30	60	52.8	W	133.2	60
18	1/4 - 3/16	70	15.3	30.0	45	60	70.1	S	66.7	76
19	3/16 - 3/16		11.5	27.0		60		N		79
20	7/32	30W	9.1	42.0	45	60	69.6	N	93.4	70

* All nozzles are Rain Bird.

Table 5. (Continued)

Farm number	Nozzle size—inches	Nozzle model*	Discharge in test section—g.p.m.	Pressure in test section—p.s.i.	Recommended design pressure—p.s.i.	Spacing of lateral—feet	Recommended spacing—feet	Wind	Percent of design pressure	Distribution efficiency—percent
21	11/64 - 3/32	40	6.5	33.0	30	60	54.0	S	110.0	88
22	13/64 - 5/32	40	12.4	45.0	40	60	61.3	N	112.5	84
23	1/4 - 7/32	70	21.3	38.0	45	80	73.5	W	84.4	32
24	13/64 - 5/32	40	11.5	38.0	40	60	60.0	N	95.0	76
25	11/64 - 3/32	40	7.2	36.5	30	80	55.5	N	121.8	63
26	7/32 - 3/16	40	15.0	34.0	45	60	63.0	N	75.5	84
27	3/16 - 1/8	40	8.2	31.0	35	40	55.5	W	88.5	54
28	7/32 - 3/16	40	11.5	22.0	45	50	52.8	S	48.8	75
29	11/64 - 3/32	40	6.7	38.0	30	60	54.0	N	127.0	73
30	3/16 - 1/8	40	8.0	32.0	35	60	55.5	N	91.5	84
31	13/64 - 5/32	40	10.2	24.5	40	60	56.5	S	61.2	6
32	3/16 - 1/8	40	9.5	40.0	35	60	58.1	N	114.2	73
33	3/16 - 1/8	40	8.5	36.0	35	50	56.5	N	103.0	83
34	3/16 - 1/8	40	8.5	29.5	35	60	56.5	S	84.3	80