When to Use Sprinkler Irrigation in Colorado

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EXTENSION SERVICE, COLORADO A & M COLLEGE
FORT COLLINS

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COVER:

Rotating sprinkler heads being used to irrigate grain near Grand Valley, Colorado.

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When to Use

Sprinkler Irrigation[1] in Colorado

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Foreword

Modern irrigation began in Colorado with the arrival of the first Mexican settlers from Santa Fe almost exactly 100 years ago. It has increased until water has been applied to about 3 million acres of crop and pasture lands. During all of this period, and with only negligible exceptions, water has been supplied to the land through surface and subsurface systems. Great expenditures of time, effort and money have been put into developing better irrigation systems and methods. Nearly all of these past efforts have been devoted to leveling fields to suitable irrigation grades and improving and perfecting surface systems for the application of water.

Within the last 3 years sprinkling has assumed an important position in Colorado as a means of applying irrigation water. The increase has been so rapid that in spite of the relatively short time of possible observation of results in the State, some help is considered necessary in acquainting prospective users with the many questions and problems arising with this form of irrigation. This publication is planned with that purpose in mind rather than providing the user with all the engineering aids required in the design of a system.

Historical

Adaptations of some form of sprinkling have been used on a field scale since the turn of the century. In nearly all early installations, permanent pipe-line locations were required which resulted in a large financial investment per acre. With the introduction of lightweight steel pipe and quick couplers in about 1930, truly portable systems were possible at a considerable re-

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[1] The work on which this bulletin is based was done in cooperation with the Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture.

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duction in cost and sprinkling took on new importance. Although the steel pipe was relatively light in weight, moving it entailed a considerable amount of arduous labor. This handicap was alleviated following World War II by the availability of aluminum tubing and castings. The resulting reduction in weight has made sprinkling more attractive to many potential users.

Portable systems were first used in Colorado in 1935. They did not prove very popular probably because of the labor involved in moving pipe and unsuitable rates of application. With the appearance of aluminum systems on the market, a new interest became apparent in 1946. In 1947 there were about 10 systems in operation. In 1948 the number increased to about 100 and prospects at this time appear good for continued growth.

What Justifies Installing Sprinkler Irrigation?

The prospective buyer of sprinkler equipment should weigh carefully the various advantages and disadvantages of sprinkler irrigation. He should keep in mind that irrigation in Colorado is an annual operation of from 3 to 9 months duration. Since power is required for sprinkling over a long period each year, the additional cost may have an important bearing on the total cost of farm operation.

All Claims Have Not Been Proved to Date

Many claims have been made for sprinkler irrigation that have not yet been substantiated under local conditions. One must not be mislead by statements of greatly increased yields through sprinkling. Such statements generally refer to comparisons between sprinkler irrigation and no irrigation.

Those who already have spent large sums in preparing land for surface irrigation should assure themselves that an additional large investment, to provide some minor advantage, is justified. Experience with sprinkler irrigation is not sufficient in Colorado to justify recommending its general use on field crops where good surface systems now exist or can be economically developed.

Ordinarily one can expect a greater irrigation efficiency with sprinklers than with surface-application methods. However, when comparison is made with well-planned and operated surface systems on the heavier soils or moderate slopes the savings, if any, may prove insignificant. Savings become very evident when comparison is made with long surface runs in permeable soils where much water is lost by deep percolation.

Claims are made that less labor is required. Here again it depends on the type of system with which the comparison is made. There will be instances where little or no savings can be effected as well as instances where savings may be considerable. It is true that workers with less irrigation experience can be used with sprinkler systems.

Many Economic Advantages

Probably the greatest economic advantage may be found in the development of new lands which have never been irrigated. This is particularly true, for example, where the land is rough or where the soil is shallow or highly erodible. The expense of leveling and ditching is avoided which may well equal the cost of sprinkler equipment. There are areas of good land entirely too rough to irrigate by any other means. Under proper control, sprinkling reduces many of the hazards of erosion. This is an important advantage which should not be overlooked when steep slopes are to be irrigated.

Small Flows of Water

Small quantities of water attached to small parcels of land often are inadequate because they cannot be efficiently applied by surface methods. The same situation arises in connection with irrigation wells of small capacity. These small streams can be efficiently utilized by sprinklers.

Starting Crops

Sprinklers may be employed in starting crops and "irrigating up" plants too small to withstand the rough treatment of furrowing out. In such instances only light irrigations are needed which can be easily accomplished by sprinklers. If the rate of application is higher than the rate of absorption or if the spray is in the form of very large drops, crusting may take place on soils that have a high clay or silt content. Very close attention must be given new seedings. The soil at the seed level should be kept moist but if a crust has formed, moisture must be applied at the critical time of emergence. Sprinkling has made it possible to grow a more extensive and better cover crop in orchards than was possible with the furrow surface method. It is also adaptable to the irrigation of some of the high value seasonal crops where light applications of water are desirable.

Fertilizer Application

Liquid fertilizers have been successfully applied through sprinklers. Usually it is introduced into the water supply on the suction side of the pump. When this is not possible it can be injected into the discharge line under pressure. Pressure sprayer equipment may be used for this purpose. By choosing a time near the end of the sprinkling period followed by a short "washing off" period, the foliage is not damaged and the fertilizer is carried down into the soil for only a short distance. Efficiency in the use of material should be greater than when applied in a surface stream because of better accuracy in the calculations and no loss in runoff. Because the rate and timing of the application is important, the work is usually done by agents supplying the fertilizer.

One other advantage frequently pointed out is the elimination of ditches which often occupy 5 percent of the land surface. With the elimination of ditches a considerable reduction of weed nuisance is also effected.

Wind Interference

Probably the greatest disadvantage in sprinkling field crops is the pattern disturbance by wind. Should the wind blow longitudinally with the lateral, the diameter of spread is reduced and the rate of precipitation on the wetted area is increased. If the wind blows from the side, the precipitation is concentrated along the lateral. The first situation can be corrected by reducing the distance between lateral settings. In the second case, improved

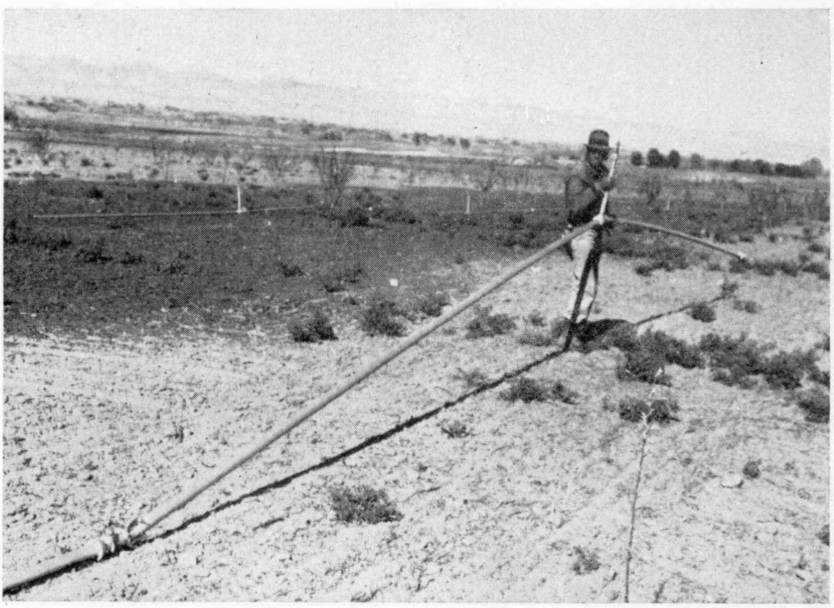

Figure 1.—Moving 2-inch sprinkler line in newly planted peach orchard. The margin between the wet and dry ground is plainly visible.

distribution also can be obtained in the same manner or by decreasing the sprinkler spacing along the lateral and replacing the spreader nozzle with a plug. These modifications of course detract from the satisfaction ordinarily experienced in the operation of a system. Also lateral lines should not be continuously set in the same location but offset on succeeding irrigations. This will help to spread the water more uniformly during the season.

Pipe Setting

Aluminum pipe in 20-foot lengths without fittings weigh 10, 15, 20, 25 and 30 pounds for the 2, 3, 4, 5 and 6-inch sizes. Those below the 6-inch size are usually carried 2 lengths at a time and a 10-year old boy can manage the 2-inch size. However there is considerable amount of walking to do in changing lines and high boots are necessary if one wishes to be protected from wet foliage. With some soils, extra lines are employed to allow the ground to firm somewhat before a line is moved. Rubber surfaced gloves are usually necessary to protect the hands from continued wetting and from pipes that have become quite hot from sun exposure when empty. Carts or trucks are necessary on long moves and some delay may occur when vehicles cannot be driven into a field for pick-up. Some trouble can be expected should it be required to move pipe at night. Considerable difficulty may be experienced in tall crops, such as corn, when the sprinklers are set on long risers and must be supported. A small amount of crop damage no doubt occurs from stepping on plants during moving operations.

Trouble with Sprinklers

Nearly all operators have experienced some trouble with sprinklers that fail to revolve or with a nozzle that has become plugged. Failure to revolve may be caused by foreign material in the bearing, the bearing being worn or most likely a partially plugged range nozzle. Not only can debris enter the pipe through the pump when the water supply comes from a ditch but also as the pipe lines are being put together. The former can be corrected only by screening. The latter can be controlled by being careful and by flushing the line prior to starting sprinkling operations. Some operators allow a small amount of water to flow through the line as it is put together thus flushing it out as it is laid.

Diseases

Plant pathologists as yet are uncertain as to whether or not the incidence of disease is increased under sprinkling. Many diseases develop and spread more rapidly in a high humidity, a condition that attends sprinkling. Experience in Colorado is too limited to determine whether a similar situation under our climatic conditions might arise. Both early and late blights have been observed in potatoes but in each case the usual control dustings may have stopped the spread as no damage occurred. Bean blight has also been observed but it has not been determined whether or not it was any worse under sprinkling than with surface irrigation. It is known that frequent showers with wind spread blight. Fungus diseases in orchards have been feared but no positive evidence of increase in their incidence thus far has been observed in Colorado or, according to reports, on apples in Washington. It would appear sensible, however, that users of sprinklers be particularly alert for the appearance of these diseases when those crops normally affected are grown.

Sprinkling versus Natural Rain

The idea that sprinkling is like natural rain needs further study and investigation under the conditions prevailing in the high arid plains and foothill areas of Colorado. Rain almost always occurs under effective cloud cover and with temperatures less than maximum. Since irrigation water must generally be used full time, day and night, when it is available, much sprinkling must be done under bright sunshine with temperatures often at 100° F. or more. The effects of these conditions on the foliage, disease and insect development and the reaction of the soil to overhead irrigation needs to be much better understood. Nighttime sprinkling provides a close approximation to natural rain and is, undoubtedly, a solution to part of the problem. Night irrigation also saves water through decreased evaporation.

Variable Water Supply

The nature of a water supply may prove to be a considerable difficulty to a sprinkler user. With surface irrigation under a canal water supply, a slightly variable flow is usually of little consequence. However the output from a sprinkler is fixed and hence there will be times when some water will have to be bypassed and applied in furrows elsewhere. During the spring runoff, a much larger flow is available to a user than later when streamflow drops or reservoir water is being used. The spring flows also carry more sediment which unless removed, will increase the rate of wear on sprinkler heads. These conditions must be taken into account by the farmer. The output from a well fits the conditions of a sprinkler system but unless the flow is confined to a pipe line, there will also be some difficulty encountered in obtaining a balanced flow.

Portable Sprinkler Systems

Only two main types of portable systems for field and orchard irrigation will be considered. One employs pipe containing small drilled holes along the top. The pressure required is low, from 6 to 15 pounds per square inch and the rate of application ranges from 1 to 2 inches depth of water per hour. The other system uses rotating sprinklers with either one or two nozzles. The average pressure required is in excess of 20 pounds, usually about 30 pounds, and may be as high as 50 pounds. The rate of application is determined by nozzle sizes, pressure, and sprinkler spacing.

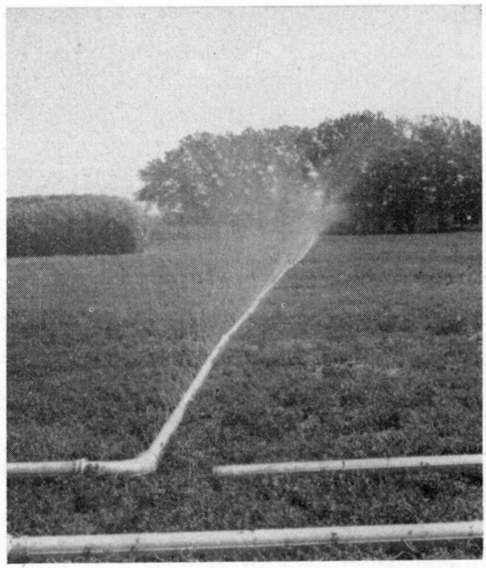

Figure 2.—Perforated pipe type of sprinkler.

Tubing

A portable sprinkler system consists primarily of either galvanized steel or aluminum tubing in sizes 2 to 8 inches in diameter and in 10, 20 and 30-foot lengths together with the necessary fittings. Aluminum tubing is standard throughout the industry but the fittings are designed by the various manufacturers and may not be interchangeable. The fittings may be fabricated in part from tubing or they may be castings. In all cases they are designed to be quickly coupled together and the joints made nearly water tight by rubber gaskets that depend for their tightness upon a pressure of about 5 pounds per square inch. Joints permit sufficient angular movement so that pipe lines can be laid around obstructions and over rough ground. However, these joints must not exceed certain limits of angularity that prevent the lifting of two 20-foot pipe lengths shoulder high at a joint and still clear low-height crops at the ends when being moved. A pipe fitting should be made in such fashion that the operator can make or unmake the connection at a distance of 20 feet by rotating the pipe. Further, provision should be made for locking it against rotation in which case it may be necessary to go to the joint for unlocking. Bases on fittings should be sufficiently wide to support a rotating sprinkler on a short riser without tipping. Tripod supports are available for long risers. Greatest trouble arises with 2-inch pipe but by laying on a slightly zig-zag line this difficulty is helped somewhat.

Perforated Pipe — Rotating Sprinkler

With perforated pipe the pattern is rectangular and no appreciable overlap is needed and planning is considerably simplified thereby. Rotating sprinklers distribute the water in a circle in varying concentrations from the center to the perimeter. To obtain uniformity it is necessary to design a system of circles that overlap to the required extent. (See figure 3). The designer must take into consideration sprinkler type, pressure and nozzle size in order to decide on sprinkler spacing along the lateral (sprinkler) line and the distance between laterals.

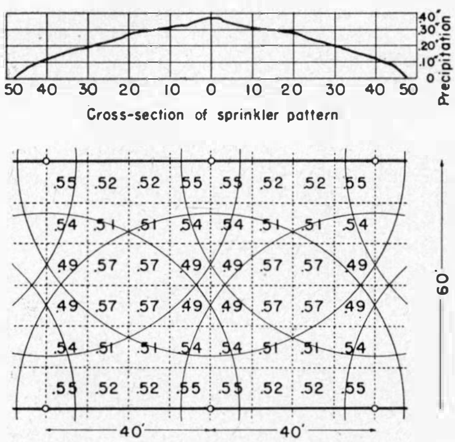

Figure 3.—Sprinklers spaced 40 feet along laterals which are 60 feet apart. The circles indicate the spread of the spray from the individual sprinklers. The overlapping results in fair uniformity of depth of application as shown by the figures within the squares. The pattern of distribution from one sprinkler is shown at the top.

The layout of piping and the location of the pump must be such as to provide efficient operation with the greatest economy in capital cost. Pipe sizes must be chosen consistent with permissible friction loss. The movement of the laterals must be thought out in detail. The number of moves per day must fit in with the farm labor program.

The Pump

The pump will be of the horizontal centrifugal type and must be chosen to deliver the correct amount of water at the desired pressure. Since high efficiency in performance is most desirable, a pump being used for other purposes is unlikely to fit the strict demands of a sprinkler system. Since the designer is often the salesman for a system, it is important to deal only with competent, experienced, and reliable agents.

Water Supply

Water may be obtained from wells, ditches or ponds. Water from a well can be pumped directly into the pipe lines but water from ditches and ponds must be screened to remove debris or moss which might cause nozzle clogging. Trash affects the two kinds of systems in different manners. Tiny hard particles may clog the small perforations that will easily pass through nozzles, but stems and parts of leaves that catch in nozzles gather at the end of a perforated pipe line and are easily flushed out by opening a valve. Fine sand that practically floats in the water even at low velocities can be quite harmful to rotating sprinklers. Coarse sand should be trapped in settling basins.

Pumping Stations

Unless there is a central pumping station, it is desirable to provide semi-permanent pumping stations along a ditch. If such a plan is followed, better screening devices can be built than those requiring portable construction. If the entire water supply is drawn through a headgate from a main ditch to a central plant, a permanent concrete structure can be built containing screens

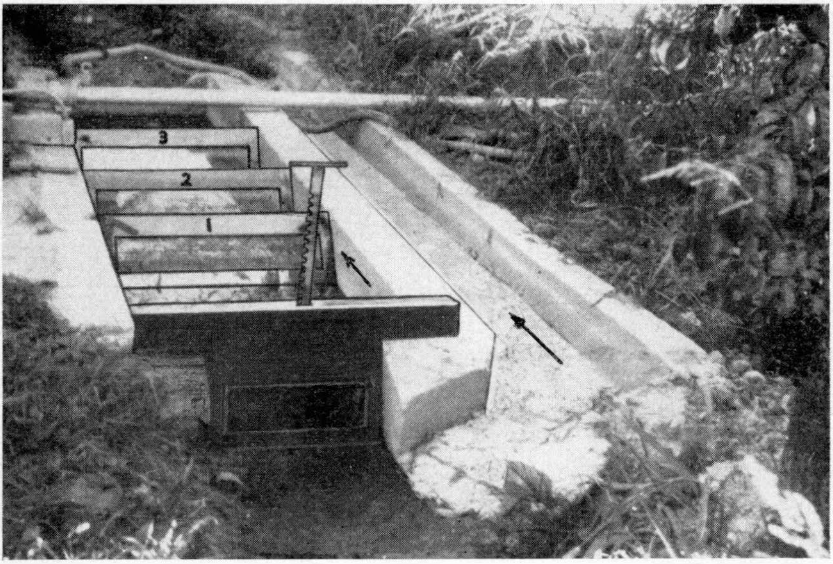

Figure 4.—A permanent pumping station. Because the gate opening is submerged, surface debris is carried off through the by-pass channel on the right. The three tilted screens, 1, 2, and 3 have progressively smaller sized openings. Movable boards at the far end permit flushing the main channel. The pump inlet is between these boards and number 3 screen. Arrows indicate direction of flow. This is a good design.

with three different sizes of openings. A structure of this character is shown in figure 4. The screens should be ample in area to avoid the necessity of frequent cleaning. Screens requiring cleaning more than three times daily, become quite a nuisance. A surface baffle board in front of the screens helps to skim off large floating material. If a box is built to serve as a sediment trap, the design should be such that the velocity of the incoming water will be low to avoid turbulence. In the construction of such a box, a drain-out sufficiently large should be provided for flushing out accumulated sediment. The pump should be placed low enough so that it will be self-priming. To guard against a water-supply failure a float operated device should be installed that will open a switch in the engine ignition circuit or interrupt the current in case of electric motor drive. Complete float operated devices are available for electric motors that will not only stop but also start them when the water supply returns to normal. In small supply ditches one might be permitted to install screens in front of the diversion gate and water could be led directly to the pump. In such a case all the usual sand and sediment which is not desirable would be discharged through the system.

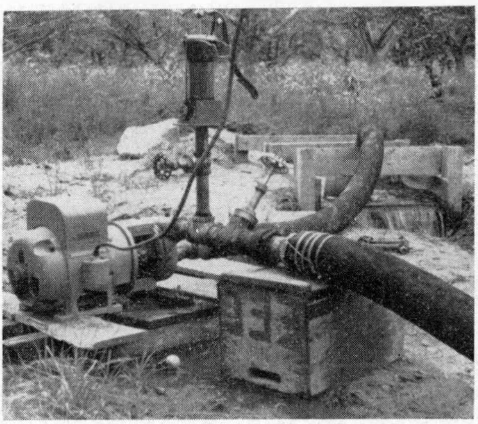

Figure 5. — Portable electric-powered pumping unit. Surplus water flows over horizontal screen. The suction hose enters from the top. Better design would be a side entrance to avoid a high spot objectionable in suction pipes.

Should the supply be drawn from a farm lateral in which there is a surplus of water, the surplus can be utilized to carry off much of the floating debris in various ways. Figures 5 and 6 indicate methods that may be employed. The important thing is a screen of ample area. It is desirable to place the pump inlet some 10 or 15 feet upstream from the control gate or dam which provides a pond on which trash can collect. If the pump is self priming and water is drawn in excess of the supply momentarily, no damage is likely to occur but air will enter the system, causing some water hammer.

Pumping Plant

In a few instances it may be possible to utilize the slope of the land to provide the necessary operating pressure. In such cases a pipe size is chosen such that after friction losses are deducted, there will be sufficient residual pressure for efficient operation. For a new development, wherein a well is the water source, a turbine or centrifugal pump can be installed that will both lift the water to the ground surface and provide the necessary pressure through pipe lines.

Portable Pumping Plant

When pumping from ditches a portable pumping plant is required. An electric motor is portable to a certain extent but the gasoline engine is the usual source of such power. Certainly electric operation is to be preferred, especially in night operation, and depending on the situation, plans may be worked out for locating a motor-driven pump along a spur service line. Consultation with officials of a power utility on such plans is recommended.

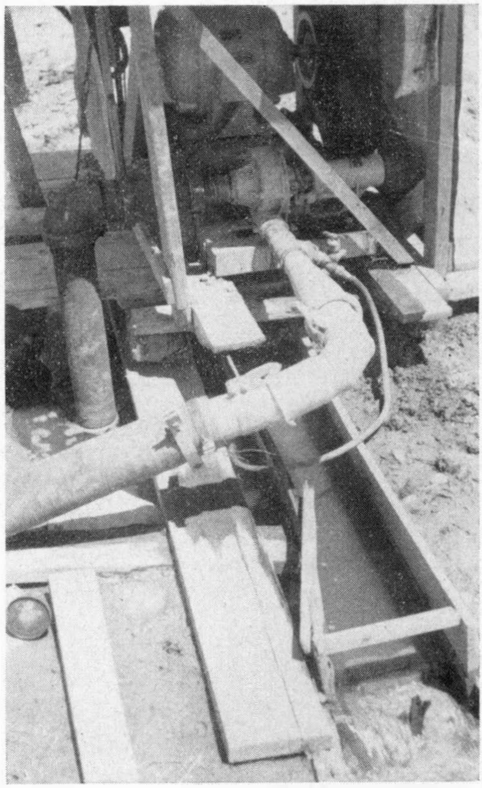

Figure 6. — Portable electric - powered pumping plant. Water flows through a single longitudinal screen and is drawn off from sump at left. Excess water passes on carrying most of the floating debris. This screen required frequent cleaning because of low capacity.

Motors

In the selection of an electric motor above 3 horsepower in size, the 3-phase induction type is much to be preferred because it is more efficient and less costly. Three-phase current is not always available and it sometimes becomes necessary to install larger single-phase motors. Power companies, however, frequently limit their size to 7½ horsepower. Air-cooled gasoline engines are desirable from the standpoint of their weight and cost but it is important that they be not operated at full load on such continuous service. Engines from other farm equipment such as those used on sprayers may be found usable as a power source. Automobile engines are generally of a size so greatly in excess of the power requirements of the usual small system that their fuel economy would be found low.

Portable pumps are exclusively of the centrifugal type on sprinkler systems as they meet the necessary conditions of pressure and capacity with minimum cost. These pumps are sensitive to speed changes which, in the case of engine drive, may be advantageous. However, changing of the pumping conditions may affect the efficiency unfavorably. Since an electric motor operates at constant speed it is important that the pump performance be closely adjusted to the requirements of the sprinkler system. The pump must therefore be chosen with care and for best satisfaction furnished by the vendor of the sprinkling equipment. In the event, then, that performance of the system proves unsatisfactory, there is no divided responsibility.

Installations involving portable pumps are shown in figures 5, 6 and 9. They can be mounted on skids, two-wheeled carts or small wagons. A rubber hose is used both on the suction side and to connect to the main feeder line.

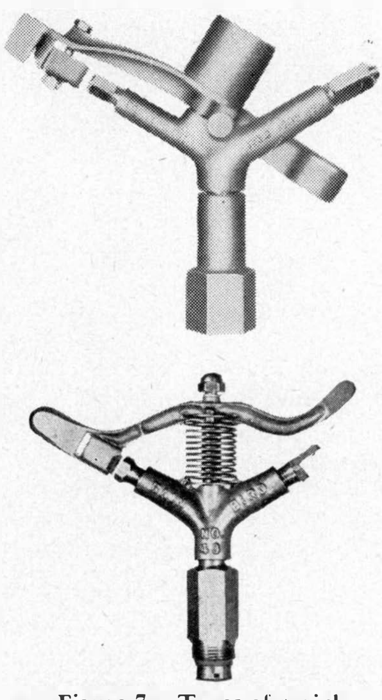

Figure 7.—Types of sprinklers used on field crops.

Rotating Sprinklers

The two kinds of rotating sprinklers in use in Colorado at present are shown in figures 7 and 8. Those in figure 7 are ordinarily used on field crops. Those in figure 8 are ordinarily used in orchards and have but one nozzle. They each are designed with replaceable nozzles so that changes from one size boring to another can be made easily. The manufacturers provide two angles of jets for their orchard sprinklers, 7° and 20° (manufacturers' designation). The 7° jet is intended to miss all but the low-hanging branches in the orchards.

Pattern of Discharge

A mound or arc-shaped cross-sectional pattern of discharge from a single sprinkler head is desirable. Pressure and size of nozzle influence the shape and diameter of the pattern. The mound shape is desired because in the necessary overlapping of circles, the parts receiving less than average from any one sprinkler are reinforced by water from an adjacent sprinkler. The complete picture of coverage is a complicated system of circles but the idea is simply illustrated in figure 3. The result is not absolutely uniform even under ideal conditions. It is not only influenced by the performance of the sprinkler head but considerably by the spacing and pressure.

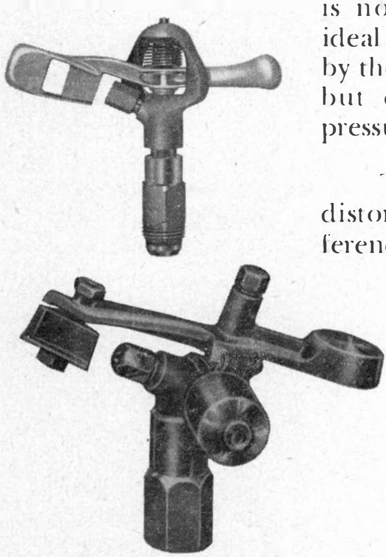

Figure 8—Orchard types of sprinklers.

The pattern of a sprinkler is badly distorted by wind and also by tree interference. When these factors are present, uniformity drops materially. It is desirable therefore that in orchards using orchard-type nozzles that the sprinkler spacing along the line be not more than 20 feet and the lines not more than 2 tree-rows apart. Further, alternating the position of the lines on successive irrigations will improve the average distribution for the season.

Design of System

Factors to Consider

Sprinkler system design is a step-by-step process requiring both skill and experience. It is an engineering problem not to be attempted by the inexperienced if satisfactory performance at minimum cost is to be expected. The designer must take into account the character and water demand of the crops, the water receptiveness of the soil, the capacity of the soil to hold water, work program of the farmer, the source of water and the shape and topography of the area to be irrigated. With these things in mind he determines the rate of application, the discharge per individual sprinkler, spacing of sprinklers, the sizes and lengths of the various pipe sections and the pump characteristics.

Crop Demands

The exact use of water by crops varies considerable according to their vigor and character. Experience has shown that a gross amount equivalent to a flow of 5 gallons per minute per acre should be a minimum value. Flows up to 10 gallons per minute per acre are not uncommon. The net use of water by crops during the period of maximum demand appears to be between 6 and 9 inches per month or 0.20 to 0.30 inch per day. The greatest demand is by alfalfa and full-grown orchards with a cover crop.

Soil Characteristics

Soils have varying capacities according to their texture, for holding water available to a plant. The sandy, coarse-textured soils may hold only ¾ inch per foot of depth while silt loams may hold as much as 2 inches. Therefore should plant-available moisture be desired in the first 3 feet of soil column, then in the first case roughly only 1½ inches need be applied in one irrigation and 6 inches in the second case. If the rate of use be 0.20 inch per day, the interval between irrigations would be approximately 8 and 30 days respectively. The rate of application is limited by the soil type and cover. Nearly all sandy loam soils will absorb water at the rate of ¾ inch per hour, sandy soils more, and heavy soils less. When covered by alfalfa or as in a pasture, the rate may be higher. It is essential that water be applied only as fast as the soil will absorb it. If applied at a faster rate resulting in runoff, the soil may become puddled and both water and power will be wasted.

The Farm Labor Problem

The farmer, when acquainted with the problem and having a definite program in mind, will probably determine for the designer how often he wishes to move sprinkler lines. With an 11-hour schedule and continuous operation, pipe will be moved morning and night allowing 1 hour for moving. This is very convenient in connection with free time for other farm duties. Five-hour sets require at least one set being made at night which is not convenient and is often omitted. Other time intervals might be considered according to the labor situation or depth of application desired. From observation of the operation of a considerable number of Colorado users it would appear that a maximum irrigation in 11 hours meets with greatest approval. However, many use 7-hour and some use 23-hour schedules. A 5-inch water application can probably be considered maximum for a sprinkler system. For many purposes as in starting germination of seedings, lesser quantities would be desired. In such cases the time could be halved or some other proportion used.

Evaporation Losses

There are certain losses that occur in sprinkling that must be taken into account. The principal one is evaporation from the water jets in the air and from the soil surface and wetted crop foliage. Evaporation has been shown by Christiansen[1] to be on the order of 2 percent providing the spray remains in the form of drops. Should it be broken up into mist by too high pressure or wind, the loss is greater. Evaporation from wetted foliage and soil surface is a much larger item because the exposed surface is extensive and the longer the exposure the greater the loss. These losses vary considerably and are almost impossible of determination but are estimated to be between 15 and 30 percent. The system capacity must be designed to include such losses.

Friction Loss in Pipes

The choice of pipe size is based upon the loss in pressure because of friction. Each sprinkler takes off some water and therefore friction decreases along the line. When the friction factor reaches a sufficiently low value, pipe size can be reduced. When the hydraulics of the line have been worked out, it must meet the test of not having a pressure drop exceeding 20 percent of the pressure at the first sprinkler. This is necessary to insure reasonable uniformity of sprinkler discharge.

Use in Orchards

In orchard sprinkling, long nozzle range is not feasible hence sprinkler spacing is much less. The usual spacing along the lateral is 20 feet and the distance between laterals is governed by tree spacing which varies from 18 feet for peaches to 30 and 40 feet for cherries and apples. Thus lateral spacing may be 20, 30 or 40 feet as the case might be. Calculations on system design then must be based on these conditions. Since tree interference is always present in an orchard, uniform seasonal depth of irrigation where laterals are placed in alternate rows, can be obtained by placing the pipe in the in-between rows on successive irrigations.

Pump Selection.

In the selection of a pump the two conditions of pressure and discharge of the sprinkler system must be met within reasonably close limits. It would be most unusual to find a pump that would exactly fit these conditions hence it becomes necessary to make some slight compromise between the two requirements. To avoid any considerable variation and since no one line of pumps is

[1] J. E. Christiansen. Irrigation by Sprinkling. Bul. 670, Uni. of Calif.

likely to fit all situations, the designer needs to have several lines to select from. It is seldom that a discarded or second-hand pump will fit the needs of a sprinkler system. Their characteristics are generally unknown and since efficiency is so important, it is unwise to give them any consideration. Many pumping units are available in one package, that is, the engine and pump are combined as a unit. Others have to be assembled on a foundation frame.

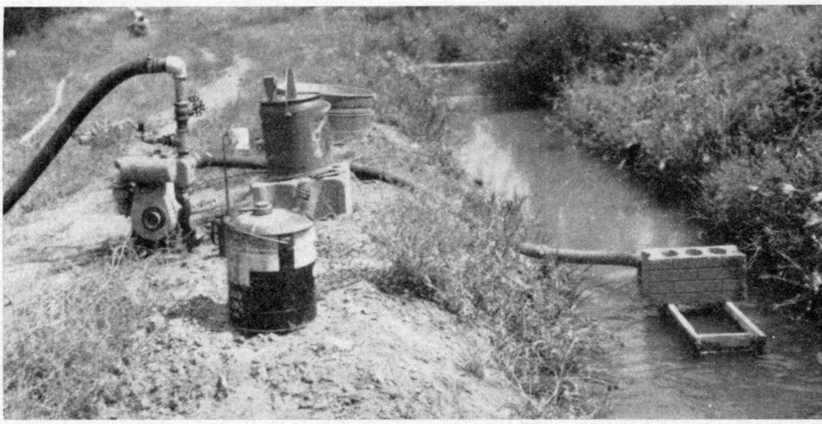

Figure 9.—Portable engine-powered pumping plant on ditch bank. Water is being drawn temporarily from within a frame covered by a screen which required frequent cleaning.

If not pumping into a pressure main, requiring that water be pumped from various places along an open ditch, a portable pumping unit will be required. Since in nearly all cases a sump and screens will be necessary, it will prove advantageous to serve several settings of a lateral, usually a minimum of three, from one pumping station. This will require from 40 to 60 feet additional pipe and some fittings.

Costs

Original Cost

The original cost is influenced by a number of factors some of which are fixed, others a matter of design. Irrigation of long narrow or irregular areas require more pipe than compact square areas. Permanent mains equipped with valves in risers will increase the first cost but save on water and labor. High rates of application will require larger pipe but may reduce the number of sprinkler lines thus making a saving. Light applications, such as might be given grain, permit more area to be covered with a given amount of equipment. The pumping unit will vary in cost according to its character. There is therefore a considerable range in the cost per acre. Of 25 systems investigated in 1948 the lowest cost per acre was found to be $25 and the highest $150. The average was $73 per acre.

Operating Costs

By making certain assumptions one can compute the cost of operating a power unit. Assume that a depth of 18 inches of water is to be applied by pumping against a 36-pound total head with an engine requiring 1 pint of gasoline per horsepower hour and a pump having an efficiency of 70 percent. Under these conditions 30.6 gallons of gasoline per acre for the season would be consumed. At 18 cents per gallon the cost would be $5.51. The cost of lubricating oil would have to be added to this sum. If an electric motor with an efficiency of 80 percent had been used, the power consumption would have been 228 kilowatt hours. At 2 cents per kilowatt hour the cost would have been $4.56 per acre for the season. Actual reports from users indicated consumptions of as low as 18 gallons and as high as 40 gallons of gasoline per acre for the season. Reports from electrical users varied from 201 to 400 kilowatt hours per acre. These differences were due principally to differences in the amount of water applied although pump efficiency and pressure have decided effects on power consumption.

Labor cost can be roughly computed on the basis of 1 man hour required to move ¼ mile of pipe. Many report that this item amounts to from ½ to ¾ man hour per acre.