

[54] **IMPROVED WATER DISTRIBUTION IN THE OPERATION OF PIVOT MOVE AGRICULTURAL IRRIGATION SPRINKLER SYSTEMS**

[72] Inventors: Donald R. Sisson; Richard E. Hanson, both of Peoria, Ill.

[73] Assignee: L. R. Nelson Mfg. Co., Inc., Peoria, Ill.

[22] Filed: July 21, 1970

[21] Appl. No.: 56,813

[52] U.S. Cl. 239/1, 239/177, 239/212, 239/230, 239/233, 239/255, 239/DIG. 1

[51] Int. Cl. B05b 17/00

[58] Field of Search.....239/177, 212, 230, 233, 255, 239/DIG. 1, 1

[56] **References Cited**

UNITED STATES PATENTS

3,143,298	8/1964	Jones	239/230 X
1,751,879	3/1930	Orr	239/255 X
2,606,789	8/1952	Royer	239/230
3,559,887	2/1971	Meyer	239/233
3,493,176	2/1970	Kinthead	239/177 X
2,816,798	12/1957	Royer	239/233 X
3,367,577	2/1968	Leasure	239/1 X

FOREIGN PATENTS OR APPLICATIONS

975,525	12/1961	Germany	239/233
1,151,145	7/1963	Germany	239/233

Primary Examiner—Lloyd L. King
Assistant Examiner—Reinhold W. Thieme
Attorney—Cushman, Darby & Cushman

[57] **ABSTRACT**

A pivot move agricultural irrigation sprinkler system in which at least a plurality of longitudinally spaced sprinkler heads adjacent the outer end portion of the conduit assembly are arranged to distribute the source of water within the adjacent portion of the conduit assembly onto the forward portion of the adjacent sprinkler head pattern area at an average application rate which is greater than the average application rate at which the water is applied to the rear portion of the adjacent sprinkler head pattern area by a ratio of the order of between 1.3 to 1 and 4.0 to 1, the water applied to the forward portion of the sprinkler head pattern area being distributed with a distribution pattern which rises rapidly to a maximum adjacent the leading portion of the sprinkler head pattern area and a sprinkler head for use in such a pivot move system having a pair of generally oppositely directed upwardly and outwardly extending outlets, an impulse arm mechanism operated by the stream issuing from one of the outlets which is smaller than the other larger and generally unobstructed outlet, for effecting a step-by-step incremental rotational movement in one direction through an arcuate extent of approximately 180° and a reversing mechanism for effecting a reverse movement of approximately 180° so that the streams from the two outlets will be distributed with a different distribution pattern and at different average application rates within two generally separate semi-circular pattern areas.

5 Claims, 10 Drawing Figures

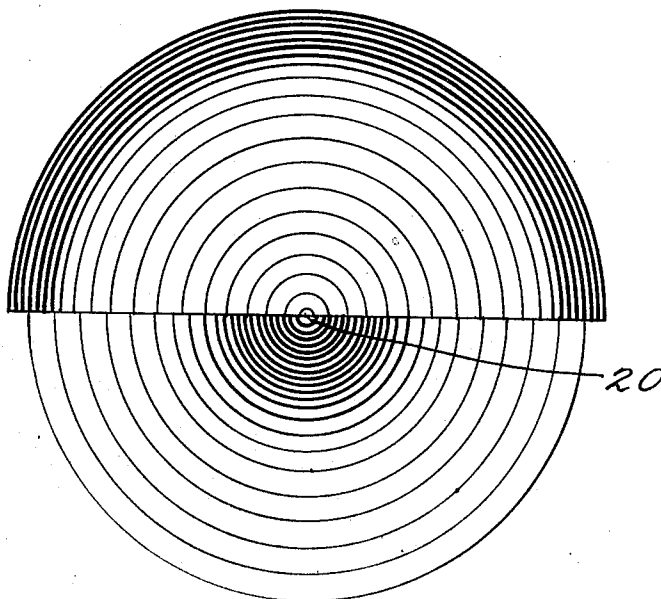


Fig. 1.

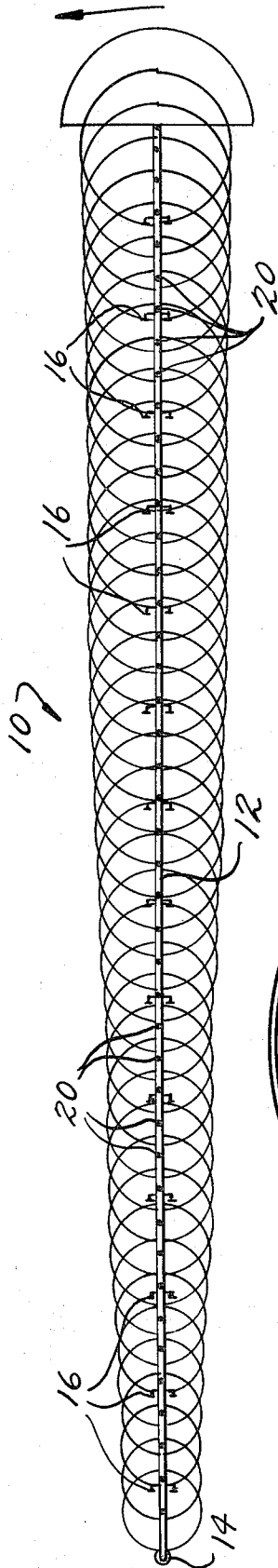
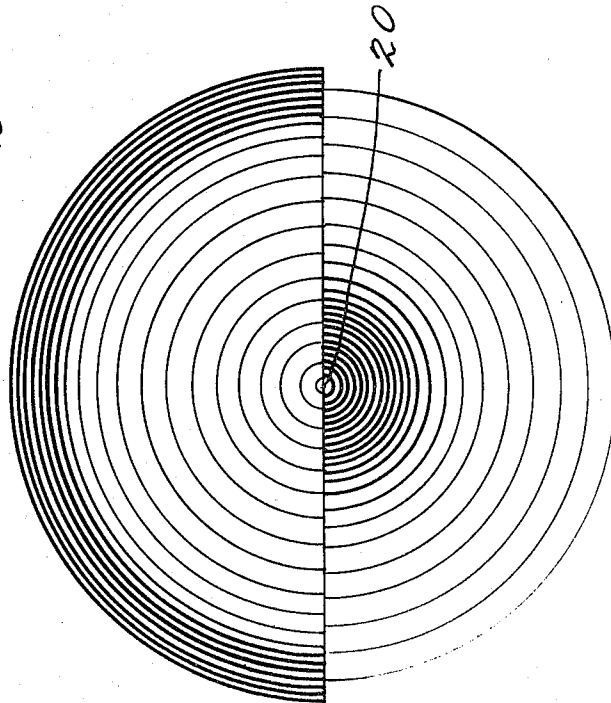


Fig. 2.



INVENTOR

DONALD R. SISSON
RICHARD E. HANSON

BY

Cushman, Dickey & Cushman
ATTORNEYS

Fig. 2.

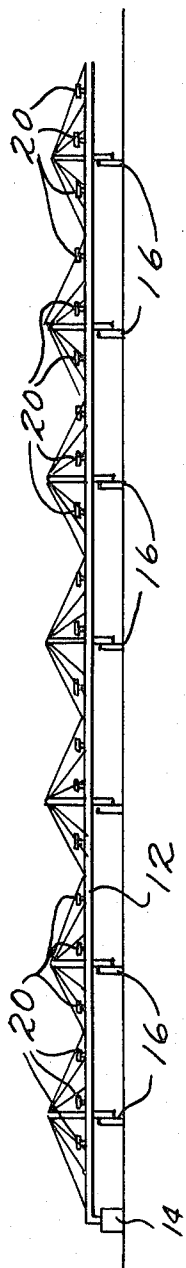
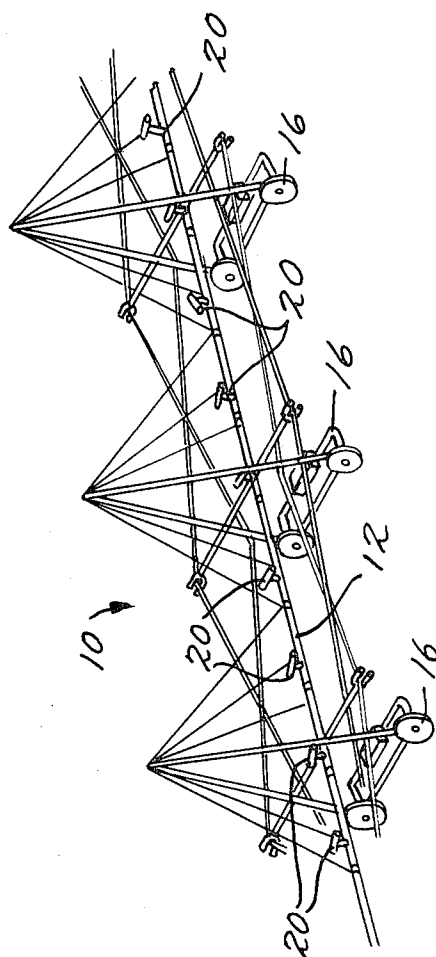
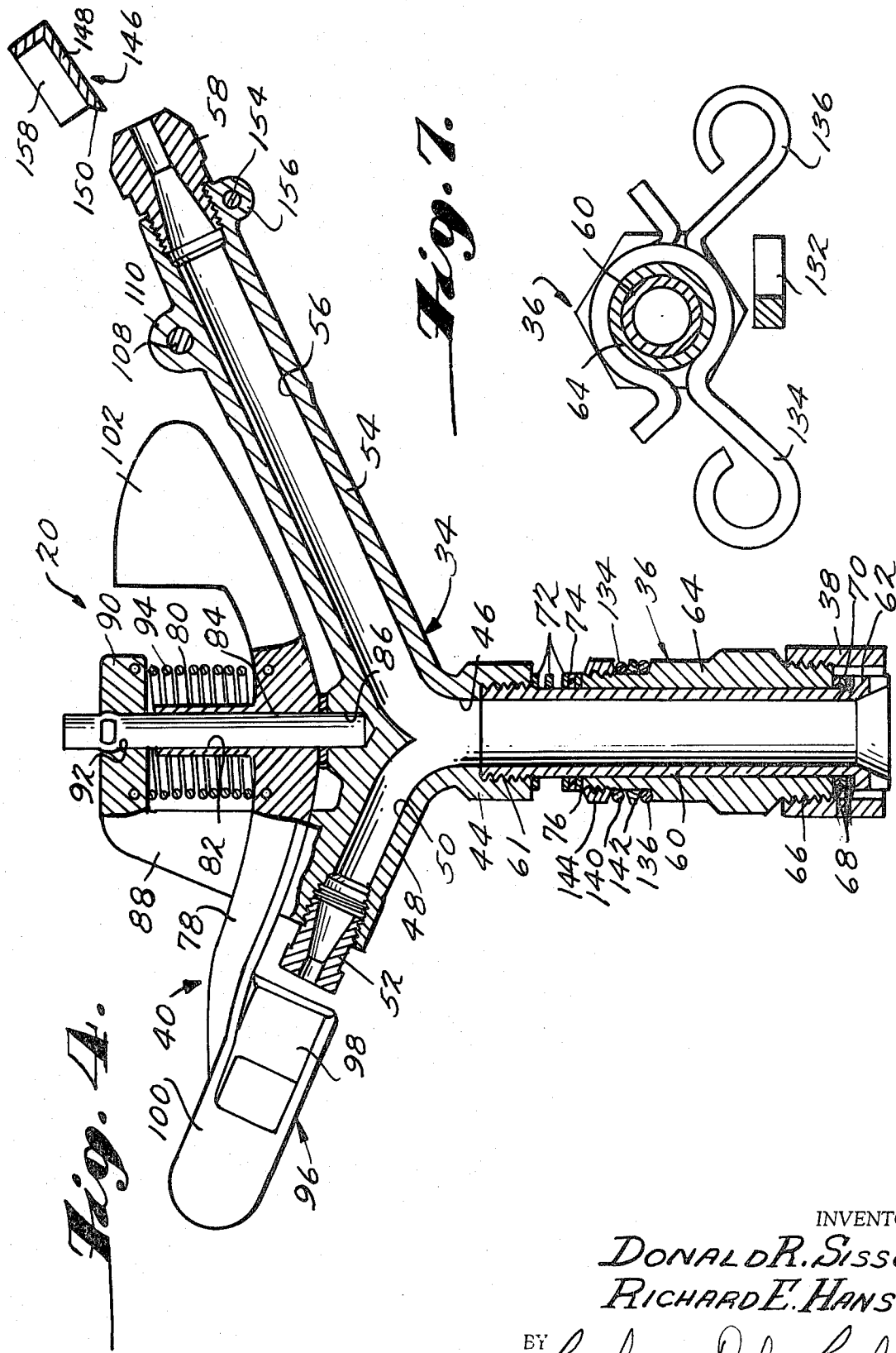


Fig. 3.

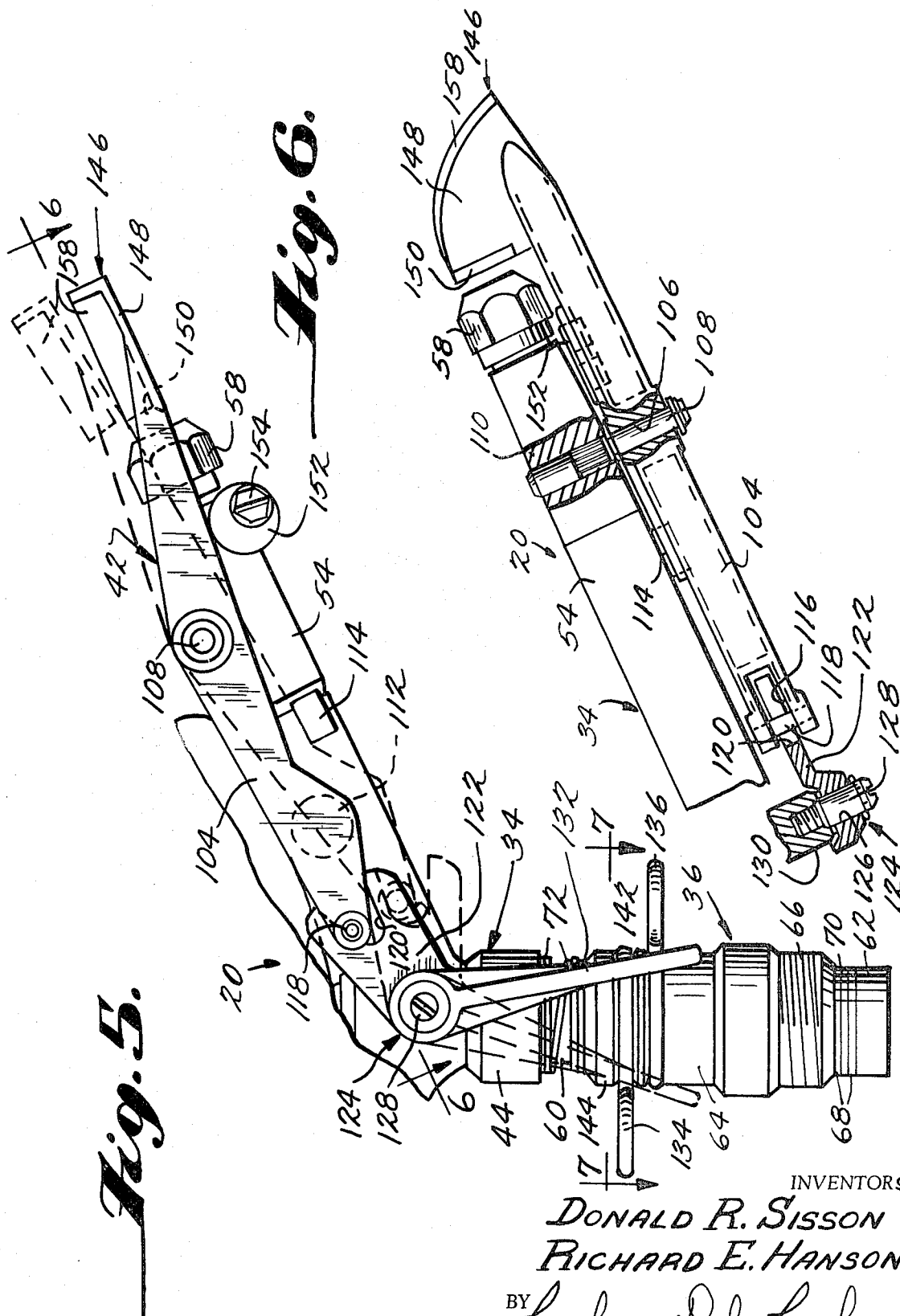


INVENTORS
DONALD R. SISSON
RICHARD E. HANSON

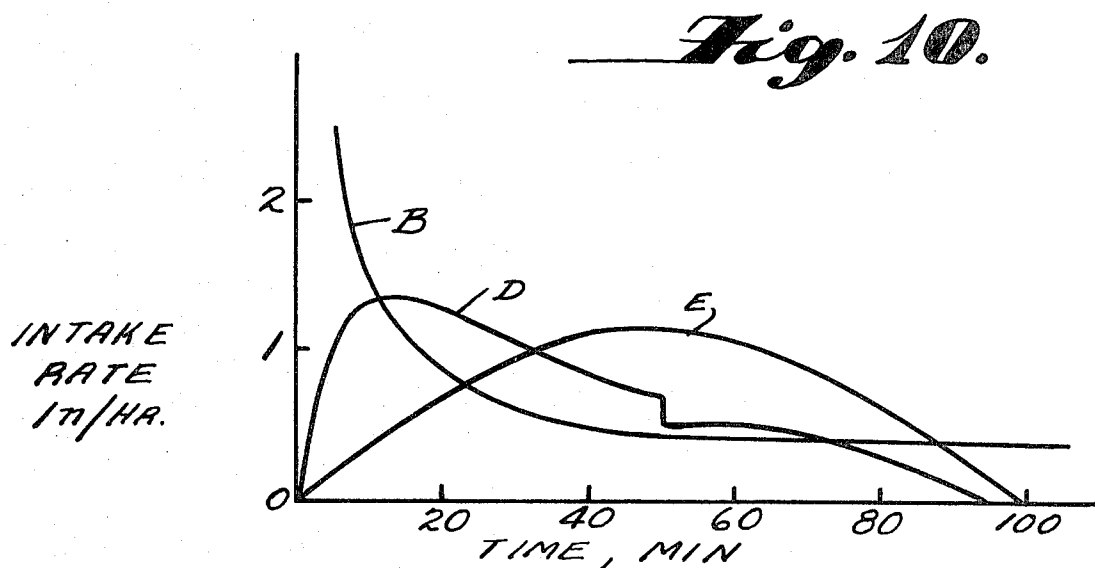
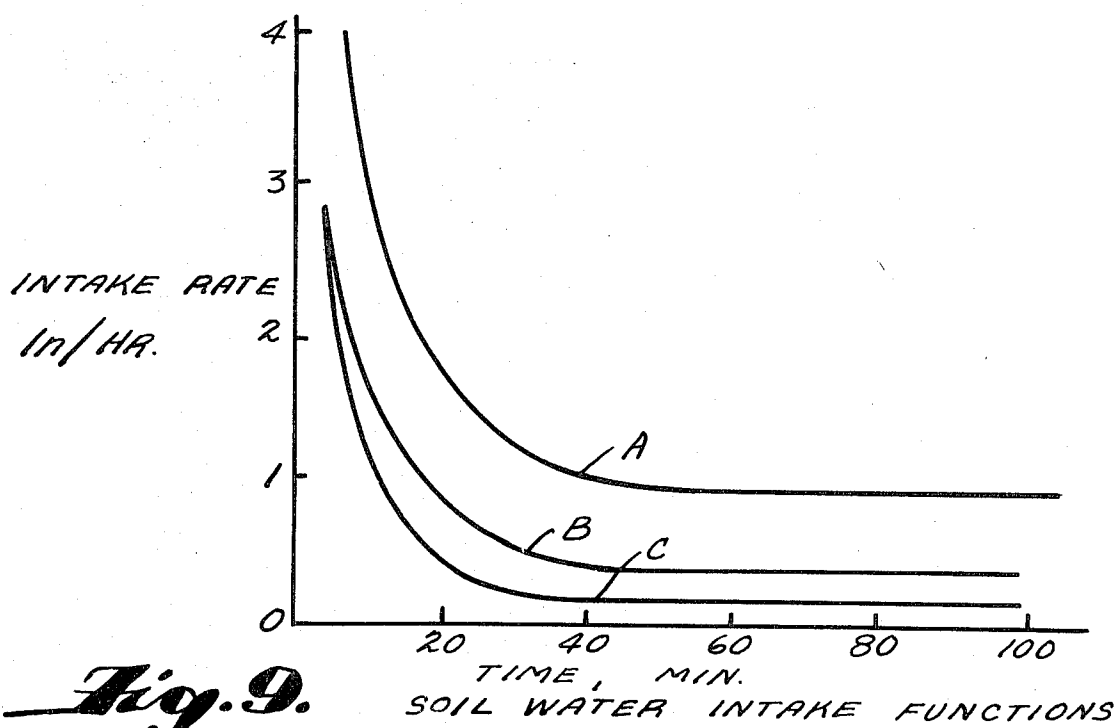
BY *Cushman, Daly & Cushman*
ATTORNEYS



INVENTORS
DONALD R. Sisson
RICHARD E. HANSON
BY *Cushman, Daly & Cushman*
ATTORNEYS



INVENTORS
 DONALD R. SISSON
 RICHARD E. HANSON
 BY *Cushman, Daly & Cushman*
 ATTORNEYS



INVENTORS

DONALD R. Sisson
RICHARD E. HANSON

BY *Cushman, Dail & Cushman*
ATTORNEYS

IMPROVED WATER DISTRIBUTION IN THE OPERATION OF PIVOT MOVE AGRICULTURAL IRRIGATION SPRINKLER SYSTEMS

This invention relates to agricultural sprinkler irrigation and more particularly to improvements in the operation of pivot move agricultural sprinkler systems embodying step-by-step rotary sprinkler heads so as to accomplish a more effective water distribution.

In recent years, the use of agricultural sprinkler irrigation has become more and more widespread. The systems heretofore proposed and now in use can be generally identified as belonging to one of two categories: first, stationary systems; and second, moving systems. As these names imply, a stationary system is one in which the water is distributed from a plurality of sprinkler heads while the sprinkler heads are maintained in a stationary position within the field. These stationary systems contemplate movement of the sprinkler heads to different stationary positions of operation within the field, but such movement is accomplished while the system is shut down.

A moving system contemplates the use of some means for effecting movement of the position of a sprinkler head or a series of sprinkler heads within the field during the operation of the sprinkler head or sprinkler heads. Examples of moving agricultural irrigation sprinkler systems which are presently commercially available are the so-called pivot move system and the traveling sprinkler system.

A pivot move system conventionally embodies a series of elongated pipe sections which are flexibly interconnected at their ends in communication with one another to form an elongated conduit assembly. The conduit assembly is connected at one end to a stationary discharge pipe in the field and supported in a horizontal position above the surface of the field by a plurality of wheel assemblies spaced longitudinally along the conduit assembly. The wheel assemblies are usually driven through water motors operated by the water under pressure within the conduit assembly to move the conduit assembly with a pivotal movement about the stationary discharge pipe as an axis. A series of sprinkler heads is mounted in communicating relation to the conduit assembly at longitudinally spaced positions therealong to distribute the water onto the field during the pivotal movement of the conduit assembly.

It will be understood that the basic purpose of any agricultural sprinkler irrigation system is to distribute a source of water to an agricultural field so as to provide the field with an amount of water (usually expressed in terms of inches) which will effectively enhance the growth of the agricultural crop in the field. In general, it can be stated that if too much water is applied, run-off will occur, resulting in crop damage, particularly to very young plants. If too little water is applied there may be insufficient water penetration within the soil resulting in poor crop root development. Consequently, to apply an effective amount of water to the field involves the distribution of the source of water to every incremental area in a generally uniform amount which is sufficient to provide adequate penetration without creating surface run-off.

The operating characteristics of a pivot move system are such as to present a wide variation in the water dis-

tribution requirements. In a pivot move system the elongated conduit assembly serves as a means for conveying the source of water to the series of spaced sprinkler heads communicating with the conduit assembly.

5 The series of sprinkler heads serves to distribute this source of water throughout an area which can be conveniently referred to as a sprinkler head pattern area. This sprinkler head pattern area is considerably less than the total area which the system is designed to cover. The total area is covered by progressively moving the sprinkler head pattern area pivotally through one revolution or a 360° arcuate extent. The dimensions of the sprinkler head pattern area and the distribution of water within the sprinkler head pattern area determine the effectiveness of the system. The width of the pattern area measured in the direction of movement of the conduit assembly determines the portion of the operating cycle (one revolution) which constitutes the water application period. In order to maintain the application period generally constant throughout the area covered, it is usual to provide a gradual increase in the width of the sprinkler head pattern in a direction outwardly of the axis. Since this relationship must be obtained by utilizing sprinkler heads having individual pattern areas which are circular, the individual circular pattern areas must be overlapped in order to prevent the width from varying from maximum to zero as would be the case with non-overlapping circular pattern areas. Moreover, as individual sprinkler pattern areas are overlapped, a problem of uniform distribution throughout the longitudinal extent of sprinkler head pattern area is encountered. This uniformity has been conventionally approached by utilizing sprinkler heads having an elliptical distribution pattern since a pattern of this type minimizes peak application rates due to overlap.

With the above in mind it can be seen that uniform variation can not be achieved in actual practice. At best, the system is designed to minimize the application of water to areas within the sprinkler head pattern area which have an excessive accumulated application rate due to overlapping and variation in the application rates within individual pattern areas. It can be seen that so long as the maximum application rate of each individual sprinkler can be maintained at a sufficiently low value, the maximum accumulated application rate will not exceed the ability of the soil to accept the water and no surface run-off will occur. A problem, however, arises because the maximum application rate of sprinkler heads increases as the capacity of the sprinkler head increases so that when it is necessary adjacent the outer reaches of the conduit assembly to utilize sprinkler heads of high capacity, the maximum application rate approaches a situation where excessive accumulated application rates are created resulting in surface run-off. Thus, in those instances where the effect of surface run-off is sufficiently damaging that run-off must be eliminated, severe limitations on the design of the pivot move system are imposed. In such cases, either the capacity of the water source must be reduced, the operational speed of the system increased or the length of the conduit assembly and hence coverage area of the system must be reduced.

It can be seen that the provision of sprinkler head means in a pivot move system, which has the capability

of operating without run-off beyond the inherent limitations of the conventional sprinkler heads of a conventional system, would have the effect of increasing the effectiveness of existing systems, either in terms of increased capacity, lengthened cycle of operation or increased coverage area.

Accordingly, it is an object of the present invention to operate a pivot move system with sprinkler head means of the type described so as to obtain the above-mentioned advantages. This objective is obtained in accordance with the principles of the present invention by distributing the available source of water to the forward portion of the sprinkler head pattern area at an average application rate which is greater than the average application rate of the water source distributed to the trailing portion of the sprinkler head pattern area and by distributing the water to the forward portion of the sprinkler head pattern area so that the distribution pattern increases rapidly adjacent the leading portion of the sprinkler head pattern area. In this way the maximum accumulated application rates (resulting from sprinkler overlap) will occur in the leading portion of the sprinkler head pattern area and will thus be applied to the soil during the operating cycle of the system at a time when the soil is relatively dry and capable of receiving water at a relatively higher application rate without run-off.

Another object of the present invention is to effect the distribution of water from a step-by-step sprinkler head onto an individual pattern area so that the water is distributed to one portion of the pattern area at an average application rate higher than the average application rate of the remaining portion of the pattern area, and with a distribution pattern in the one portion which is maximum adjacent the periphery and decreases toward the axis of the sprinkler head and with a distribution pattern in the remaining portion which is maximum adjacent the axis of the sprinkler head and decreases toward the periphery thereof.

These and other objects of the present invention will become more apparent during the course of the following detailed description and appended claims.

The invention may best be understood with reference to the accompanying drawings wherein an illustrative embodiment of the invention is shown.

In the drawings:

FIG. 1 is a top plan view of a pivot move irrigation sprinkler system embodying the principles of the present invention;

FIG. 2 is a fragmentary side elevational view of the pivot move system shown in FIG. 1;

FIG. 3 is a fragmentary perspective view of a portion of the pivot move system shown in FIGS. 1 and 2;

FIG. 4 is a vertical sectional view of a preferred step-by-step rotary sprinkler head embodying the principles of the present invention;

FIG. 5 is a fragmentary side elevational view of the sprinkler head shown in FIG. 4 illustrating the normal inoperative position of the return mechanism in dotted lines and the operative position thereof in solid lines;

FIG. 6 is a fragmentary sectional view taken along the line 6—6 of FIG. 5;

FIG. 7 is a fragmentary sectional view taken along the line 7—7 of FIG. 5;

FIG. 8 is a top plan view of the individual pattern area of the sprinkler head with the distribution pattern indicated by shade lines;

FIG. 9 is a graph illustrating the water intake functions of various types of soils; and

FIG. 10 is a graph illustrating the relationship between the water intake function of one particular soil and the application rate of a portion of a pivot move system embodying the principles of the present invention in comparison with the application rate of a comparable portion of a conventional pivot move system.

Referring now more particular to FIGS. 1-3 of the drawings, there is shown therein a pivot move agricultural irrigation system, generally indicated at 10, which embodies the principles of the present invention. As shown, the pivot move system 10 includes a pipe or conduit assembly 12. One end of the conduit assembly is swivelly connected for pivotal movement about an upright axis with a vertically extending supply pipe or conduit 14. The portion of the conduit assembly 12 extending outwardly from the supply pipe 14 is supported above the ground by a plurality of ground engaging assemblies 16 operatively connected with the conduit assembly at longitudinally spaced positions therealong.

The construction and operation of the assemblies 12 and 16 as well as the construction of the source pipe and the manner in which the source pipe is fed a supply of water under pressure is fully disclosed in Zybach U.S. Pat. No. 2,604,359. See also Gordan U.S. Pat. No. 2,893,643, Zybach U.S. Pat. No. 2,941,727 and Harris U.S. Pat. No. 3,484,046 for improvements therein. For purposes of the present invention, it is sufficient merely to note that the conduit assembly 12 is connected in communicating relation with the source of water under pressure flowing from the source pipe 14 and that a portion of the water under pressure flowing in the conduit assembly is utilized as a power source for propelling each of the ground engaging assemblies 16 so that the entire conduit assembly is moved in a plane parallel with the field about the vertical axis of the source pipe at a predetermined rate of speed. A detailed understanding of the manner in which this function is accomplished can be obtained by reference to one or more of the aforesaid patents. It will be understood that the rate of movement of the ground engaging assemblies increases as their position along the conduit assembly from the source pipe increases. It will also be understood that the means for converting the water under pressure into propulsion movement includes a compensating mechanism for varying the speed of propulsion to accommodate variations in the terrain of the field to insure that the conduit assembly will be maintained in substantial longitudinal alignment. The construction of the mechanism for accomplishing this compensating propulsion movement is likewise fully disclosed in the above-mentioned patents, all of which are incorporated by reference herein and to which reference may be had if necessary. The pivot move system 10 also includes a series of step-by-step rotary sprinkler heads, generally indicated at 20, mounted in longitudinally spaced relation along the conduit assembly 12. The sprinkler heads 20 communicate with the water under pressure within the conduit assembly and serve to distribute the water onto the field during the operative pivotal movement of the system.

The series of sprinkler heads 20 include at least a plurality of improved sprinkler heads constructed in accordance with the principles of the present invention.

Referring now more particularly to FIGS. 4-7, as shown, each improved sprinkler head 20 includes a sprinkler body assembly 34 and a bearing and seal assembly 36 for connecting the sprinkler body assembly in communicating relation with a riser pipe or the like 38 which, in turn, is communicated with a source of water under pressure. The bearing and seal assembly 36 also serves to support the sprinkler body assembly 34 for rotational movement about an upright or vertical axis.

The sprinkler head 20 also includes an impulse arm mechanism, generally indicated at 40, which is operable, when the sprinkler body assembly 34 is communicated through the bearing and seal assembly 36 with a source of water under pressure, to effect a step-by-step rotary movement of the sprinkler body assembly about its rotational axis in one direction.

The sprinkler head 20 also includes a reversing mechanism, generally indicated at 42, which is operable when the sprinkler body assembly 34 has been moved into a predetermined position of rotation by the impulse arm assembly 40, to effect a rapid pivotal movement of the sprinkler body assembly in the opposite direction from the first-mentioned predetermined position into a second predetermined position.

Referring now more particularly to FIG. 4, the sprinkler body assembly 34 includes a main casting or body having a lower inlet portion 44 defining a water inlet passage 46 therein. Extending upwardly and outwardly from the inlet portion 44 at an angle of approximately 25° with respect to the vertical is a first outlet portion 48 having a water outlet passage 50 therein which communicates at its lower end with the inlet passage 46 and at its outer end with a nozzle member 52 threadedly engaged within the outer end of the outlet portion 48.

Extending upwardly and outwardly from the inlet portion 44 at an angle of approximately 25° with respect to the vertical is a second outlet portion 54. The outlet portion 54, like the outlet portion 48, includes an outlet passage 56 which communicates at its lower end with the inlet passage 46 and its outer end with a nozzle member 58 threadedly engaged within the outer end of the outlet portion 54. The axes of the outlet passages 50 and 56 and the axis of the inlet passage 46 are all disposed within a common vertical plane so that the streams issuing from the nozzles 52 and 58 are directed upwardly and outwardly in symmetrical relation to the common plane, each stream being displaced with respect to the other approximately 180° measured arcuately about the axis of the inlet passage 46.

The bearing and seal assembly 36 includes an inner tubular member 60 having its upper end exteriorly threaded, as indicated at 61, to engage interior threads formed on the lower end of the inlet portion 44 of the sprinkler body assembly 34. The lower end of the tubular member 60 is provided with an annular flange 62 which extends radially outwardly therefrom. Journalled on the central outer peripheral portion of the tubular member 60 is a riser pipe connecting member 64, the lower outer periphery of which is threaded, as indicated at 66, for engagement within cooperating interior threads formed in the upper end of the riser pipe 38.

A lower seal assembly in the form of a pair of outer rubber washers 68 and an inner Teflon washer 70 is mounted on the inner tubular member 60 between the annular flange 62 thereof and the lower end of the member 64. A coil spring 72 mounted in surrounding relation to the upper end of the inner tubular member 60 between the lower end of the sprinkler body inlet portion 44 and the upper end of the member 64 serves to resiliently maintain the washers 68 and 70 in engagement between the members 60 and 64. Preferably, an upper sealing assembly including an upper rubber washer 74 and a lower Teflon washer 76 is mounted between the lower end of the spring 72 and the upper end of the member 64.

It can be seen that the member 64 is thus fixedly supported on the upper end of the riser pipe 38 and the sprinkler body assembly 34 is rotatably supported within the member 64 by virtue of its fixed connection with the tubular member 60. The spring 72 and sealing washers 68, 70, 74 and 76 provide a controlled frictional resistance to the rotation of the sprinkler body and at the same time effectively seal the water under pressure flowing from the riser pipe 38 through the tubular member 60 and into the sprinkler body 34.

As shown, the impulse arm mechanism 40 is of generally conventional construction and includes an arm structure 78 having a cylindrical portion 80 extending upwardly from the central portion thereof which is formed with a throughbore 82, to receive a shaft or pin 84. The pin 84 has its lower end fixedly engaged within a bore 86 formed in the upper central portion of the sprinkler head body 34 to thus support the impulse arm 78 for pivotal movement about the axis of the pin. As shown, the axis of the pin 78 is coincident with the axis of the inlet passage 46 and the axis of rotation of the sprinkler body assembly 34.

Extending upwardly from the upper outer end of the outlet portion 48 is an integral impact portion 88 which is adapted to be engaged by an adjacent portion of the impulse arm 78. The impact portion 88 has an integral pin mounting portion 90 extending horizontally from the upper end thereof which is centrally apertured, as at 92, to receive the upper end of the mounting pin 84. A coil spring 94 is mounted in surrounding relation to the cylindrical portion 80 of the impulse arm 78 and has its upper end connected to the mounting portion 90 and its lower end connected with the central portion of the impulse arm 78 so as to resiliently bias the impulse arm in a direction to maintain the arm in engagement with the impact portion 88.

The end of the impulse arm adjacent the outlet nozzle 52 is provided with a stream engaging spoon or reactant element, indicated at 96. The spoon includes an inner portion 98 having a stream engaging surface which is disposed in a direction such that when the stream impinges thereon the reaction force of the stream acts in a direction to move the impulse arm into engagement with the impact portion 88. The stream engaging surface of the inner portion 98 is inclined in a direction to direct the stream engaged thereby to a generally oppositely facing outer stream engaging surface provided on a spaced outer portion 100 which is shaped and positioned so that when the stream engages the same, the reaction force thereon will act in a direction to move the impulse arm 78 away from the impact portion 88.

The operation of the impulse arm mechanism 40 is conventional in nature. Briefly, it can be seen that since the reaction force acting on the outer portion 100 acts through a greater lever arm than the reaction force on the inner portion 98, the impulse arm 78 will be moved about its axis in a direction away from the impact portion 88. During this impulse movement, the spring 94 is stressed until the pivotal movement of the impact arm is completely arrested at which time the spring 94 serves to effect a pivotal movement of the impulse arm in a direction toward the impact portion 88. During the latter portion of this return movement the stream issuing from the nozzle 52 will first engage the inner portion 98 which acts in a direction to move the impulse arm in a direction to engage the latter with the impact portion 88. When the impulse arm 78 impacts or engages the impact portion 88, the sprinkler head assembly will be moved incrementally a predetermined arcuate distance under the frictional control of the bearing and seal assembly 36.

In accordance with conventional practice, the opposite end of the impulse arm 78 is provided with a counterbalancing portion 102 which is of a shape and size to provide both weight and wind resistance balance to the impulse arm.

As best shown in FIGS. 5 and 6, the reversing mechanism 42 includes a reversing arm 104 provided with a transverse bore 106 intermediate the ends thereof. The bore rotatably receives one end of a shaft 108, the opposite end of which is fixedly engaged within a boss 110 integrally formed on the upper outer end of the outlet portion 54 of the sprinkler body assembly 34. The inwardly extending portion of reversing arm 104 is provided with a weight 112 which biases the arm 104 to pivot about the shaft 108 in a counterclockwise direction as viewed in FIG. 5. Pivotal movement of the arm 104 in a counterclockwise direction is limited by engagement of the lower surface of the inner portion of the arm with a stop lug 114 formed integrally on the outlet portion 54 and extending transversely outwardly therefrom.

The inner end of the reversing arm 104 is bifurcated as indicated at 116 and apertured to receive a spring pin 118. The central portion of the spring pin 118 extending across the bifurcated end 116 of the arm engages within a slot 120 formed in the outer end of an arm 122 of an actuating bell crank lever, generally indicated at 124. The bell crank lever is provided with an opening 126 extending transversely through the central portion thereof for receiving one end of a pivot pin 128, the opposite end of which is fixedly mounted within a transversely extending boss 130 formed as an integral part of the sprinkler body assembly 34. As shown, the axis of the pin 128 is generally coincident with the intersection of the axes of the outlet passages 50 and 56 and the inlet passage 46.

The actuating bell crank lever 124 also includes a downwardly extending actuating arm 132, the lower end of which is adapted to be selectively engaged by a pair of adjustable elements 134 and 136.

As best shown in FIGS. 5 and 7, each of the elements 134 and 136 is preferably constructed of a metal rod of circular cross-section having its central portion bent into a generally circular configuration of a size and shape to engage around an upper cylindrical peripheral

portion 140 of the member 64. As best shown in FIGS. 4 and 5 the circular portions are mounted on the cylindrical portion 140 with a washer 142 disposed therebetween and each element extends generally radially outwardly from the respective circular portion in a position to be engaged by the lower end of the actuating lever arm 132. The outer end of each element 134 and 136 may be bent to provide finger engaging portions to aid in the manual adjustment of the elements into their desired selected positions of operation. In order to retain the elements 134 and 136 in their selected positions of operation, a nut 144 is threadably engaged with the upper end of the cylindrical portion 140. It will be understood that by tightening the nut 144, the circular portions of the elements 134 and 136 will be clamped and maintained in the position of adjustment to which they have been selectively moved.

Mounted on the outer end of the reversing arm 104 is a reaction element, generally indicated at 146. The reaction element includes a generally segmentally shaped wall or plate 148 which is secured to the outer end of the arm 104 in any suitable manner. As shown, the segmental plate 148 forms an integral part of the arm structure. The plate 148 includes a portion extending laterally from the outer end of the arm which is provided with an angular surface 150. When the reaction element 146 is disposed in a position within the stream issuing from the outlet nozzle 58, the reaction force of the stream on the surface 150 acts in a direction to pivot the reversing arm in a clockwise direction as viewed in FIG. 5. The clockwise pivotal movement of the reversing arm 104 is limited by an adjustable cam stop 152. As shown, the cam stop is in the form of a disc which is rotatably adjustably mounted on the outer end of the outlet body portion 54 by a bolt 154 extending through the cam stop 152 in eccentric relation and engaged within an appropriate boss 156 formed integrally on the outer end of the outlet portion 54 of the sprinkler body assembly 34.

The reaction element 146 also includes an arcuate wall 158 which extends upwardly from the arcuate edge of the segmental plate 148. As best shown in FIGS. 5 and 6, the arcuate wall 158 is positioned so as to be engaged by the stream issuing from the outlet nozzle 58 when the reaction surface 150 is disposed within the stream. The reaction of the stream against the arcuate surface of the wall 158 creates a reaction force which acts in a direction to pivot the sprinkler body assembly in a counterclockwise direction as viewed in FIG. 6.

The manner in which the reversing mechanism 42 operates is similar to the operation of the reversing mechanism disclosed in commonly-assigned copending application Ser. No. 823,026 filed May 8, 1969, now U.S. Pat. No. 3,559,887 in the name of Larry P. Meyer. Briefly, it will be understood that the reversing arm 104 is normally biased, as by the weight 112, into a limiting position wherein the stop 114 is engaged and the reaction element 146 is disposed out of the path of the stream issuing from the nozzle 58 as shown in dotted lines in FIG. 5. It will also be noted that bell crank lever 124 is biased by its center of gravity so as to be disposed in a limiting position corresponding to the above-mentioned limiting position of the reversing arm 104.

The operation of the impulse arm mechanism 40 is such as to effect an operative clockwise step-by-step rotational movement of the sprinkler body assembly with respect to the tubular member 64 of the bearing and seal assembly 36 (as viewed in FIGS. 6 and 7). During this step-by-step rotary movement, the lower end of the actuating lever 132 will be moved with the sprinkler body assembly into a position of engagement with the element 134 fixedly carried by the member 64. Further rotational movement of the sprinkler body assembly will effect a counterclockwise pivotal movement of the bell crank lever 124, as viewed in FIG. 5, which, in turn, will effect a clockwise pivotal movement of the reversing arm 104, thus moving the reaction surface 150 into the stream issuing from the nozzle 58, as shown in solid lines in FIG. 5. The reaction force created as a result of the impingement of the stream on the surface 150 maintains the reversing arm 104 into a position limited by the adjustable cam stop 152. At the same time, the impingement of the stream issuing from the nozzle 58 against the surface of the arcuate wall 158 will effect a counterclockwise movement of the sprinkler body assembly about its pivotal axis, as viewed in FIGS. 6 and 7. This pivotal movement which is continuous and rapid will occur until such time as the lower end of the actuating arm 132 engages the element 136 so that further movement will cause a clockwise pivoting of the bell crank lever 124, as viewed in FIG. 5, which, in turn, effects a counterclockwise pivotal movement of the reversing arm 104 thus moving the reaction element 146 out of the stream issuing from the nozzle 158 into the dotted line position shown.

As previously indicated, the pivot move agricultural irrigation system 10 utilizes a series of sprinkler heads 20. In the system shown in FIG. 1, there are 42 heads in the entire series. The sprinkler heads vary in size and capacity depending upon the position at which they are mounted along the conduit assembly 12. In general, the size and capacity increase as the distance outwardly of the pivotal axis of the system increases. As shown, the outermost sprinkler head is preferably of a type such as disclosed in the aforesaid Meyer application. The next 12 heads are of the improved construction described above. The remainder of the heads may be of a conventional design. It will be understood that the number of heads of improved construction may be varied.

In accordance with the principles of the present invention, the adjusting elements 134 and 136 of each improved sprinkler head are positioned so that the sprinkler head will operate under the action of the impulse arm assembly 40 through an arcuate extent of approximately 180° and be returned by the reversing mechanism 42 through an arcuate extent of approximately 180°. Moreover, the positions of the elements 134 and 136 are so chosen with respect to the direction of movement of the conduit assembly 12 that the outlet nozzle 58 directs the stream issuing therefrom forwardly with respect to the direction of travel during the midpoint of the 180° movement.

OPERATION

Referring now more particularly to FIG. 1, it will be understood that when a source of water available in source pipe 14 is communicated with the conduit as-

sembly 12, the conduit assembly will serve to communicate the source of water to the individual sprinkler heads 20 and to the water motors of the ground engaging assemblies 16. By virtue of the communication of the source of water to the series of sprinkler heads 20, the overwhelming majority of the source water will be distributed by the sprinkler heads onto the adjacent part of the field within a sprinkler head pattern area which, as shown in FIG. 1, includes the total area defined by the individually overlapped pattern areas of the series of sprinkler heads. The communication of the source of water to the water motors of the ground engaging assemblies simultaneously effects a pivotal movement of the conduit assembly about the axis of the source pipe so as to progressively move the sprinkler head pattern area through a circular system pattern area.

As previously indicated, because of these operating characteristics of the system, the sprinkler heads adjacent the outer end portion of the conduit assembly must have the capability of distributing a relatively large quantity of water within a relatively short application period.

The improvements of the present invention are particularly concerned with the distribution of water under these high capacity short application period conditions presented adjacent the outer end portion of the conduit assembly. Since the last sprinkler presents a special circumstance which forms a relatively insignificant portion of the entire sprinkler head pattern area, the effect of the last sprinkler head is disregarded in the discussion to follow. As previously indicated the 12 sprinkler heads adjacent the outermost sprinkler head are of the improved construction described above. The improvements in the system secured by these heads can best be understood first by reference to the distribution characteristics of a single improved sprinkler head and then by considering the effect of overlapping these individual distributions.

The distribution characteristics of the sprinkler head 20 can perhaps best be expressed in terms of the average application rate and the distribution pattern associated with each outlet nozzle. The term "average application rate," when related to the equipment, can conveniently be considered as being equal to the amount of water that flows through the sprinkler head divided by the total field area to which the water is applied (evaporation loss being neglected). The term contemplates variations in the actual application rate throughout the total area to which the water is applied, including zero application rates for short intermittent periods within an extended application period. By viewing the application rate in this way such variables as wind velocity, relative humidity conditions, changes in ground contour, etc., all of which can change the actual distribution of the water coming from a moving sprinkler head, can be disregarded.

If it is assumed that a constant source of water under pressure is available, as for example, a given capacity in terms of gallons per minute, a sprinkler head which is capable of distributing this source of water over the greatest area will have the least average application rate. It is generally recognized in the art that a given source of water under pressure can be distributed from a single point to the greatest area by flowing the source

through a nozzle which projects the source in a stream extending upwardly and outwardly at a known predetermined angle (e.g., approximately 25°). Even a stationary nozzle of this type would have the capability of distributing water at a lower average application rate than the same nozzle directed upwardly along a vertical axis or an annular nozzle capable of distributing the same source throughout a 360° area at the same angle.

Moreover, with a nozzle capable of distributing the source of water upwardly and outwardly in the manner set forth above, it is also possible by moving the nozzle about a vertical axis to apply the water to an area extending 360° about the axis. Where this rotary movement is effected at a relatively slow rate as, for example, of the order of one revolution per minute, the circular pattern area to which the source of water is applied has a maximum radius. On the other hand, where this rotation is effected rather rapidly, the radius of the circular pattern area decreases. For the reasons set forth above, it is well known that sprinkler heads which operate at slow rotational speeds, such as conventional step-by-step rotary sprinkler heads, have the capability of distributing a given source of water with an average distribution rate which is considerably below that of other types of sprinkler heads, such as whirling sprinkler heads or stationary sprinkler heads.

The vast difference between the average application rate of a conventional step-by-step rotary sprinkler head in comparison with a conventional stationary sprinkler head of comparable capacity is also evident when it is considered that the actual or instantaneous application rate of a step-by-step rotary sprinkler is intermittently being applied to different segmental areas of its circular pattern area, whereas the instantaneous application rate of a stationary sprinkler head is continuously applied to the same circular area. Thus, the average application rate of a stationary sprinkler head is equal to the instantaneous or actual application rate, whereas the average application rate of a conventional step-by-step rotary sprinkler head is considerably less than the instantaneous or actual application rate (which is in itself less than that of the stationary sprinkler head as noted above) due to the fact that the application rate is applied over a greater area over a period of time equal to or greater than the time required to effect a complete cycle of rotary movement. Moreover, the intermittent application of the water throughout a single cycle of operation has a somewhat advantageous effect due to the inherent characteristic of soil to recover its ability to take in more water without run-off.

When dealing with the relatively high capacity conditions presented by the outer reaches of a pivot move system, it will be understood that sprinkler heads of the stationary or whirling type have inherently such high average application rates as to be inapplicable to the present invention. Thus, the present invention is limited to the utilization of sprinkler heads, such as step-by-step rotary sprinkler heads having operating characteristics capable of delivering a large capacity water source at average application rates within a range which can be received over an application period of one hour or more without excessive run-off.

Commensurate with the above, it will also be understood that the average application rate of step-by-

step rotary sprinkler heads of the same design will increase as the size or capacity of the sprinkler head is increased. In terms of a single nozzle of a single sprinkler head, this means that the average application rate will increase as the size of the nozzle orifice increases. With the above in mind, it can be seen that the sprinkler head 20 oriented in the manner described above has the capacity of distributing the source of water flowing through it to the forward portion of its pattern area at a higher average application rate than the rearward portion of its pattern area because of the greater orifice area size of the forwardly directed nozzle in relation to the orifice area size of the rearwardly directed nozzle. In the embodiment shown, the ratio of the relative orifice area sizes of the larger nozzle to the smaller nozzle is approximately 2½ to 1. This ratio can be varied within an operative range of the order of between 1.3 to 1 and 4.0 to 1, a preferred range being of the order of between 2 to 1 and 3 to 1.

It will be understood that these ratios likewise represent the ratio of the average application rate of the forward portion of the pattern area of the sprinkler head to the average application rate of the rearward portion of the pattern area. The same ratio exists with respect to the sprinkler head pattern area of the system which is made up of a series of individual pattern areas disposed in fixed overlapping relation.

The distribution curve within the sprinkler head pattern area measured in the direction of forward travel can likewise be related to the equipment by considering the condition in which the water flowing through the sprinkler head is allowed to leave the structure of the sprinkler head.

In the preferred embodiment shown, the water leaves the larger forward outlet nozzle 58 in a relatively unobstructed condition. That is, the amount of time that the reversing mechanism 42 interrupts the flow in relation to the time required for the sprinkler head to complete an operating cycle is relatively small. On the other hand, the water flowing through the rear small nozzle 52 leaves the sprinkler head in a relatively obstructed condition since the impulse arm mechanism 40 continuously oscillates throughout the cycle of operation at a relatively rapid speed of the order of 200 times per minute. Consequently, it terms of a complete operating cycle the impulse arm mechanism 40 obstructs the flow from the rear nozzle a relatively greater proportion of the time.

As is well known in the art of conventional full circle step-by-step rotary sprinkler heads, a relatively unobstructed nozzle in a full circle step-by-step rotary sprinkler distributes the water in what is known as a doughnut shaped distribution pattern. On the other hand, an impulse arm interrupted nozzle of a full circle step-by-step rotary sprinkler head distributes the water in what is known as an elliptical distribution pattern. These patterns when translated to curves on a graph plotting application rates in inches per hour against feet from the center line of the sprinkler head axis along a straight line have shapes which are generally similar to the upper half of the profile of a horizontally disposed bar bell and the upper half of an ellipse, respectively.

For present purposes these distribution curves indicate the number of inches per hour applied to any point or small incremental area along a straight line

passing through the axis of the sprinkler head. Thus, in the case of an unobstructed nozzle in a full circle step-by-step rotary sprinkler head, the distribution along the line from one end to the other would follow a curve which initially increases quite sharply to a point where the majority of the unobstructed stream falls on the ground, then diminishes rather rapidly to a relatively low value which is relatively constant through the axis of the sprinkler head and beyond until a similar abrupt rise and fall is encountered at the other end of the line. On the other hand, the curve relating to a nozzle interrupted by an impulse arm in a full circle step-by-step rotary sprinkler head initially increases gradually from one end until the center line is reached, where the application rate is the greatest. Beyond the center line the application rate decreases gradually. In general, it will be noted that an unobstructed nozzle will distribute a greater amount of water to the periphery of the pattern area whereas a nozzle which is continuously obstructed by a rapidly oscillating impulse arm tends to distribute a greater amount of water toward the center portion of the pattern area.

With the above in mind, it can be seen that by utilizing the reversing mechanism to maintain the relatively unobstructed larger nozzle such that it will distribute water to the forward portion of its pattern and the smaller relatively obstructed rearward nozzle to the rearward portion of its pattern area, the distribution pattern of the improved sprinkler head 20 will be as indicated by the shade lines in FIG. 8. The graphic representation of this distribution pattern along a line extending in the direction of forward movement and measured from the leading edge thereof to the trailing edge thereof will have a configuration extending forwardly of the center line which generally corresponds in shape to the shape of the doughnut distribution curve of a comparable full circle nozzle extending forwardly of its center line. Likewise, the shape of the distribution curve rearwardly of the center line will correspond to the shape of an obstructed nozzle full circle elliptical distribution curve extending from the center line to the periphery thereof.

As previously indicated, an object of the present invention is to achieve a more effective distribution of water in known pivot move agricultural irrigation systems. Effectiveness in this context contemplates the distribution of the source of water over a field area within a time period adequate to obtain sufficient water penetration into the soil for good crop root development while at the same time limiting the amount of water applied over the field area throughout the time period of application so as to minimize the establishment of any appreciable surface water run-off. A determination of such effectiveness involves the interrelationship between the amount of water applied per unit time, the ability of the soil to accept the amount of water applied thereto without appreciable run-off and the overall time period during which the water is applied.

A graphical interrelationship of these three factors is shown in FIG. 9 wherein there is illustrated a family of curves obtained by substantially continuously applying water uniformly over a predetermined field area at different rates in terms of inches per hour over a period of time expressed in terms of minutes and plotting the

time at which surface run-off will occur with the different types of such utilizing the different application rates. As shown, there are three curves indicated by the reference characters A, B and C, representing respectively sandy loam soil, silt loam soil and clay loam soil. It will be noted that the shape of the curves is generally the same, all indicating that soils generally are capable of receiving water at relatively high application rates for only a relatively short application period without appreciable run-off, but that where the water is applied at relatively low application rates run-off will not occur over extended periods of application. Moreover, as the application rate decreases from such relatively high rate to such relatively low rate the time period within which run-off will occur increases at a variable rate which is initially very small and finally quite extended.

Expressed in its simplest terms, the underlying principle of the present invention is that improved effectiveness can be obtained by distributing the water to the field at rates throughout the overall application period which vary in a manner approximating the variation in the application rates throughout the application time period represented by an average one of the curves shown in FIG. 9.

The application of the aforementioned underlying principle to a pivot move system of the type described is accomplished in accordance with the present invention by distributing the source of water to the forward portion of the sprinkler head pattern area at a relatively higher average application rate than that of the rearward portion and by distributing the source of water to the forward portions along a distribution curve measured in the direction of transverse movement which rises relatively sharply at the leading edge portion of the sprinkler head pattern area.

Referring again to the above-described distribution curve relating to a single improved sprinkler head 20, the distribution curve relating to the series of sprinkler heads disposed in fixed spaced overlapping relation can be considered generally similar in shape. The greatest change in the contour of the distribution curve as a result of overlapping of the individual patterns throughout the sprinkler head pattern area is to increase the amount of water applied to the part of the forward portion of the pattern adjacent the plane of the center lines of the sprinkler heads.

It will also be understood that the overlapping of individual patterns has a tendency to even out the distribution along the longitudinal extent of the sprinkler head pattern area. That is, the amount of water delivered to any point along a line parallel to the plane of the center lines of the sprinkler heads tends to assume the contour of a relatively straight line. While it is recognized that there will be variations in the distribution curve measured longitudinally within the sprinkler head pattern area, such variation may be disregarded for present purposes. By disregarding such variations it can be generally stated that the distribution curve when measured in the direction of movement, that is, generally transverse to the longitudinal extent of the sprinkler head pattern area, will have a distribution curve of generally the same shape at any place throughout the longitudinal extent where improved sprinkler heads 10 are employed. Of course, the magnitude of the curve increases as the position from the source pipe increases.

Since these distribution curves graphically illustrated in terms of average application rates applied throughout the adjacent portion of the sprinkler head pattern area measured in the direction of travel are also a graphical expression of the average application rate applied to any point or incremental area within the corresponding portion of the system pattern area progressively throughout the entire application period due to the forward movement of the conduit assembly, the effectiveness of the water distribution obtained by the improved sprinkler heads 20 in the system can be graphically illustrated by superimposing an exemplary distribution curve on an average soil intake function curve taken from the graph shown in FIG. 9.

Such a composite graphical representation is illustrated in FIG. 10. The curve indicated at B is from FIG. 9. The curve indicated at D represents the distribution curve obtained by the system of the present invention at a position adjacent the improved heads 20, as, for example, at the head which is fourth from the end of the conduit assembly 12. This graph also includes the graphical representation of the distribution curve indicated at E obtained at a comparable radial position by a conventional pivot move system. Specifically, the conventional pivot move system represented is of a commercially known design having a water source capacity in terms of gallons per minute of 1,000 gpm. The conduit assembly of the system is approximately 1,285 feet and has conventional full circle step-by-step rotary sprinkler heads spaced along the conduit assembly approximately every 32 feet beginning 10 feet from the pivotal axis of the conduit assembly. The last sprinkler head is a high capacity reversing sprinkler head set to distribute water within a semi-circular pattern area similar to that shown in FIG. 1. It will be understood that the capacity of the sprinkler heads increases as their position from the pivotal axis increases. The system has a cycle of operation of 50 hours per revolution. The system of the present invention as shown in FIG. 1 is comparable to this system except for the elimination of the first sprinkler head and the utilization of the 12 improved sprinkler heads 20 at the 12 penultimate positions adjacent the outer end portion of the conduit assembly.

With reference to FIG. 10, it will be noted that the area beneath the curves D and E represents the total number of inches applied to an incremental area of the soil over which the particular sprinkler head passes during one cycle of operation. In general, it will be noted that the area under the curve D is equal to the area under the curve E. The incremental portions of these curves which are disposed above the curve B represent potential surface run-off. The term potential surface run-off is used because the point of intersection between line B and the distribution curves D and E does not designate the precise point at which run-off will begin. There will be some lag until the actual soil saturation builds up as a result of the previous variable application of the curves D and E, whereas the saturation assumed at curve B is as a result of build up at a substantially constant application rate equal to that of the point on line B.

It can be seen that the incremental area above curve B relating to the curve D is considerably less than the corresponding incremental area of the curve E. This reduction is accomplished by the distribution of the im-

proved sprinkler heads 20 wherein the distribution rate rapidly increases to a maximum in the leading portion of the sprinkler head pattern area. In contrast, conventional full circle step-by-step rotary sprinkler heads have a maximum application rate adjacent the axis. Thus, with the present invention the maximum application rate is applied at a time when the soil is relatively dry and capable of receiving water at a relatively high application rate without appreciable surface run-off. In contrast, where the maximum occurs at the midpoint of the application period, as in distribution curve E, the soil will be substantially saturated and therefore incapable of receiving this maximum rate without the creation of appreciable surface run-off.

Thus, it can be seen that the improved distribution of the present invention is achieved first by insuring that the water is distributed to the forward portion of the sprinkler head pattern area at a higher average application rate than to the rearward portion thereof and next, by applying the water to the leading portion of the sprinkler head pattern area along a distribution curve which increases sharply to a maximum at a position near the leading portion of the sprinkler head pattern area. It will be understood that while 180° operative and reverse strokes are preferred to obtain this distribution curve, strokes somewhat less than 180°, as for example 120°, are within the contemplation of the present invention.

It will be understood that insofar as the system of the present invention is concerned, the underlying principles of the present invention can be carried out by sprinkler head constructions other than the preferred construction described above, as, for example, the sprinkler head constructions disclosed in commonly-assigned, pending application Ser. No. 56,809, filed concurrently herewith in the name of Richard E. Hanson and Raymond F. Lippitt could be utilized. The improved sprinkler head construction described above is preferred, however, including the reversing arm mechanism 42, because of its operating characteristics of rapidly effecting the return stroke of the sprinkler head. It will be understood, however, that it is within the contemplation of the present invention to utilize conventional return mechanisms.

It thus will be seen that the objects of this invention have been fully and effectively accomplished. It will be realized, however, that the foregoing specific embodiment has been shown and described only for the purpose of illustrating the principles of the invention and is subject to extensive change without departure from such principles.

What is claimed is:

1. In a method of distributing a source of water under pressure onto a field made up of soil having the capability of receiving water without appreciable surface run-off at a relatively high average application rate when relatively dry and at a relatively low application rate when relatively saturated with water with the use of a pivot move agricultural irrigation system including elongated conduit means for receiving a source of water under pressure at one end and conveying the water under pressure in a generally horizontal direction toward the opposite end thereof, a series of step-by-step rotary sprinkler heads spaced longitudinally along said conduit means in communicating relation

therewith for distributing water under pressure within said conduit means incrementally onto the field in step-by-step rotary fashion within overlapping individual pattern areas defining a predetermined sprinkler head pattern area having first and second portions disposed on opposite sides of said conduit means, and means for supporting said conduit means above and generally parallel with the surface of the field and for effecting an arcuate movement of said conduit means about an axis adjacent said one end thereof in a direction toward said first pattern area portion along a predetermined circular path in the field while said conduit means is communicated with a source of water under pressure to distribute the same onto the field through said series of sprinkler heads within a predetermined system pattern area substantially greater than said predetermined sprinkler head pattern area by progressively moving the position of said predetermined sprinkler head pattern area within said predetermined system pattern area in said direction, the improvement which comprises the steps of operating at least a plurality of said series of sprinkler heads adjacent the opposite end portion of said conduit means so as to distribute the water under pressure within the longitudinally adjacent portion of said conduit means to the first pattern area portion covered thereby with an average application rate which is higher than the average application rate in said second portion covered thereby by a ratio of the order of between 1.3 to 1 and 4.0 to 1 and varying the application rate within the first pattern area portion covered thereby such that the distribution pattern increases rapidly adjacent the leading portion of the sprinkler head pattern area covered to an extent sufficient to insure that the maximum accumulated application rate is applied to the soil while in a relatively dry condition, thus minimizing the creation of appreciable surface

run-off.

2. The improvement as defined in claim 1, wherein each of said plurality of sprinkler heads is operated so that water under pressure is continuously flowing therefrom in a first stream in a direction upwardly and outwardly in generally symmetrical relation to a plane passing through the axis of rotation and in a second stream in a direction upwardly and outwardly in generally symmetrical relation to said plane positioned on the opposite side of the axis of rotation, the amount of water flowing in said first stream being greater than the amount of water flowing in said second stream by a ratio of the order of between 1.3 to 1 and 4.0 to 1, and so as to be moved about its axis of rotation in repeated operating cycles including an operative movement in one direction about its axis and a return movement in the opposite direction about its axis between two predetermined positions of rotation of an arcuate distance such that said first and second streams will be applied to generally separate corresponding first and second segmental pattern areas disposed respectively within the first and second portions of said sprinkler head pattern area, said first stream being substantially unobstructed during the operative movement of said sprinkler body so as to be distributed within said first segmental pattern area with a distribution pattern which is maximum adjacent the periphery thereof and decreases toward the axis of said sprinkler body.

3. The improvement as defined in claim 2, wherein said first and second segmental pattern areas are each of an arcuate extent of approximately 180°.

4. The improvement as defined in claim 1 wherein said ratio is of the order of between 2 to 1 and 3 to 1.

5. The improvement as defined in claim 1, wherein said ratio is approximately 2½ to 1.

* * * * *

40

45

50

55

60

65