DEVELOPMENT OF AUTOMATED SURFACE IRRIGATION

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INTRODUCTION

The popularity of surface irrigation is decreasing, mostly because of high wages and the difficulty of obtaining suitable help. Even graded fields that formerly were irrigated by surface methods are being irrigated by sprinklers. This change has resulted from technological advances that have been made in the development of sprinkler systems. The traditional requirement of labor for irrigation is being replaced by large capital expenditures for automatic sprinkler systems.

This trend indicates that more research and development are required to automate surface irrigation more fully so that it can compete with other methods of irrigation.

SURFACE IRRIGATION

Surface irrigation includes all irrigation methods that use the soil surface as a medium on which water moves and spreads over the irrigated area under the force of gravity. Surface irrigation methods are distinct from pressurized systems, in which the water is distributed on the land through pipes under pressure.

Water for surface irrigation can be conveyed by means of open canals, pipes, or flumes to the point of release, but from that point on it flows under the influence of the gravitational force.

Furrows, border strips, and basins are used in the more popular surface irrigation methods and have been subject to automated surface irrigation developments. Automatic devices that obviate the necessity for manual control have been developed. Such devices release water according to a predetermined schedule, thus reducing the labor requirement and the need for the operator to be present.

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REQUIREMENTS FOR AUTOMATIC SURFACE IRRIGATION

An automatic surface irrigation system must be: 1. simple, reliable, and easily maintained; 2. priced at a cost the farmer can afford to pay; 3. economical to operate; 4. able to distribute water efficiently and uniformly; 5. capable of applying as little as 5 cm and as much as 15 cm of water per irrigation; 6. operable manually if necessary or desirable; and 7. able to fail safely without damage to field or equipment when its components malfunction.

PRESENT STATE OF DEVELOPMENT

Controls for Open Canals

Since 1960, several agricultural engineers in the United States have been working on the development of components such as gates and valves that can be operated by a timer or by remote controls in order to eliminate the need for an operator to be present during irrigation (8). The earliest step in this direction involved the placing of automatic dams and gates in open canals (1).

Irrigation can commence at either the upper or the lower end of a supply canal. Where the system is designed to commence water delivery at the lower end, all the check gates in the canal except the last one must be open. As irrigation proceeds upstream, gates are closed one at a time in sequence until the water delivery is completed. On the other hand, when water delivery starts at the upper end of the supply canal, the check gates in the canal are closed. As irrigation proceeds they are opened in sequence until irrigation is completed.

Semiautomatic check dams were developed for controlling water flow in furrow irrigation (10). Each dam is made of a butyl rubber sheet supported in a metal frame designed to fit the cross section of a lined canal. When the dam is in the closed position the top edge of the rubber sheet is supported by a nylon drawstring threaded through brass grommets. When the drawstring is released by a timer or manually, the rubber sheet is pressed to the bottom of the ditch by the weight of water, permitting practically unobstructed flow. These rubber check dams are closed manually before the next irrigation.

The flow of water in a canal can be controlled with a metal drop check (9) consisting of a rigid sheet-metal gate mounted on a metal frame that fits the cross section of a lined irrigation canal. The gate is pivoted from the upper frame and, when in the open position, allows water to pass freely below it. When released manually or by a timer, the gate drops, thus checking the flow. The gates must be set manually in their open position before the next irrigation can be applied.

The metal flap-gate is useful in unlined canals (9). This gate is mounted on a galvanized steel cut-off wall installed in the canal at right angles to the flow. The gate is held in the closed position by a latch, which is released by a timer or manually at the completion of the irrigation. This type of gate can be fitted with a sinking float, which allows the gate to be reset at any time between irrigations. When so equipped, the float initially adds buoyancy to the gate and keeps it open. A small hole in the float admits water into the float at a controlled rate. When the float is full of water, the structure closes by its own weight or its weight in combination with the pressure of water in the canal. At the start of an irrigation it is necessary only to turn water into the canal. As each float sinks and the gate closes, water is delivered at the next outlet along the canal.

The concept of using cutback flows from open canals for furrow irrigation was developed by Garton (6). This system utilizes a concrete-lined supply canal constructed in a series of level steps down the slope. Furrow spiles are installed in the side of the canal at the same elevation in each bay. At the start of an irrigation a high initial flow enters the furrow from the spiles. The initial stream is reduced in size after the water reaches the end of the furrow by lowering the water level in the canal. The flow of water in the canal is controlled by check dams operated either manually or by timers. Water release and flow control were carried out according to the judgment of an operator either manually or by timers.

Valves for Low-Pressure Pipelines

Considerable emphasis has been placed recently on the development of equipment that permits automatic release of water from low-pressure pipelines. Fischbach and Goodding (3), Fischbach and Somerhalder (4), and Haise and Fischbach[a] have developed low-cost valves and systems for controlling water discharge from closed systems. Fischbach and Goodding (3) reported on an automated irrigation valve for controlling flow from a low-pressure pipeline. The cylindrical housing of this valve contains a doughnut-shaped butyl rubber inner tube attached to a compressed-air line. When air from this line is allowed to inflate the inner tube, the opening in the valve body closes and the flow of water stops. When the air is released, the water pressure in the pipeline deflates the inner tube, flattening it against the side of the valve body, thus enabling the water to pass through freely. Air-activated valves can be controlled automatically or manually from a central location through small-diameter air lines, eliminating most of the walking associated with surface irrigation.

A cylindrical inflatable rubber tube has been developed[b] that fits inside a section of an 8-inch (20.3-cm) pipe and is connected to a plastic supply line. Inflating the tube stops the flow of water; deflating the tube releases the water. Inflation is accomplished by having the water in the plastic supply line at a higher pressure than that in the pipeline. Timers can be used to trigger deflation and water release. As an additional feature, a drainline connects all valves in sequence so that when one valve opens the one behind it closes. Thus, the water flows through only one valve at a time.

Early developments in controlling water included a pneumatic closure or diaphragm that fitted a valve of the alfalfa or orchard type (7). The flow of water to furrows from an underground pipeline was controlled by a valve at each pipe riser. Water for furrow irrigation was distributed from gated pipes attached to hydrants equippped with an alfalfa valve and a hydraulic diaphragm. The valves were operated by compressed air and controlled by three-way solenoid valves.

Miscellaneous Equipment

In addition to the major components, several other devices have been developed that improve the automated distribution and control of water.

Automatic siphon tubes were developed by Worstell (11). These are equipped with cups at each end that maintain the prime after the water in the supply canal has been shut off. The first models were designed to hold enough water in the attached cups to withstand 10-14 d of evaporation. These siphon tubes are great labor savers because they do not require priming between irrigations or when flow is interrupted as, for example, during a power failure.

Pressure gates, designed to regulate flow in open channels (10), are equipped with counterweights or are spring-loaded. They are set in a canal at right angles to the flow and are pivoted below the center of gravity. When the water level rises to a predetermined height at the upstream side, the gate trips and remains open as long as water is running in the canal. When the flow stops, the gate closes automatically.

Weir outlets were developed to regulate flow from turnouts[b] and are used in conjunction with pipe turnouts in open channels. They consist of a sheet of metal mounted on the side of the canal that prevents water from entering the turnout pipe until a desired water level is reached. The device eliminates the need for communication between all turnout structures and provides a nearly uniform flow from all the turnouts in a particular portion of the supply canal. Several of the structures can be installed between two consecutive flow control gates in the supply canal.

Timers are essential parts of a semiautomatic surface irrigation system. The simplest timers probably are converted alarm clocks. Because exposure to moisture and dust shortens the life of an ordinary alarm clock, a special 24-h timer for use in activating irrigation structures has been developed by a Japanese manufacturer[b].

Electric controls appear attractive for controlling irrigation water (5). Bowman (2) developed a system that can operate turnout gates by radio signals. Irrigation can be commenced by sending a radio signal from any convenient location chosen by the operator. For terminating the water flow, special sensor-transmitters operated by batteries are placed at the lower end of border strips. A sensing element based on the conductivity principle is utilized in the system. When the water reaches a predetermined depth at the end of a border strip, the sensing device triggers a signal that activates a motor that closes the headgate. Although the sensing device is suitable for stopping the flow, the start of an irrigation must be initiated by the operator. Closing of a gate in one border strip can be made to trigger the opening of the next gate, making the sequential operation automatic.

Soil moisture sensors are necessary for completely automatic irrigation. Tensiometers connected to electric controls are suitable for triggering the end of an irrigation but are not satisfactory for starting water application because their operating range is below 0.8 bar of soil moisture tension. To overcome this difficulty Phene *et al.*[c] developed a matric potential sensor that operates over a wide range of soil moisture levels and has an electrical output for use in controlling irrigation systems. The matric potential sensor measures heat dissipation in a porous body as a function of its water content.

SYSTEM DEVELOPMENT

Various combinations of components can be used in designing semiautomatic or fully automatic surface irrigation systems. Pressurized systems are easiest to automate; next in order are furrow *and border* methods of surface irrigation.

The concept of recirculating irrigation water has been included in some designs. Fischbach and Bondurant[d] propose the use of recirculation of runoff water to increase the uniformity of water application and reduce the labor requirement. With this approach the maximum allowable stream is turned to each furrow and

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[a] Haise, H.R. and P.E. Fischbach. 1970. Auto-mechanization of pipe distribution systems. Journal Paper No. 2957, Nebr. Agr. Exp. Sta., Lincoln, Nebr.

[b] Humpherys, A.S. Private communication.

[c] Phene, C.J., G.J. Hoffman, and R.S. Austin. 1971. Controlling automated irrigation with a soil matric potential sensor. Paper No. 71-230, Amer. Soc. Agr. Eng., St. Joseph, Michigan.

[d] Fischbach, P.E. and J.A. Bondurant. 1970. Recirculating irrigation water. Journal Paper No. 2956, Nebr. Agr. Exp. Sta., Lincoln, Nebr.

the runoff water is collected in a sump from which it is pumped back to the supply system. Irrigation would continue until the desired amount of water has been applied.

The use of reduced or cutback flows in surface irrigation systems improves water distribution efficiency considerably and reduces the runoff from fields. Apart from the work of Garton (6), relatively little attention has been paid to this important aspect of surface irrigation. Admittedly it is difficult to achieve under automated conditions. Equipment designed to control the flow of water from low-pressure pipe systems usually permits only full flows and complete shutoffs, with no provision for regulating the flow rate. Such control devices cannot be used to adjust the irrigation rate toward the end of an irrigation application.

EVALUATION OF THE PRESENT STATE OF DEVELOPMENT

The object in developing automated surface irrigation is to produce simple, inexpensive, easy-to-manufacture components that can function without an operator. Gas and oil pipelines and municipal water systems have been controlled automatically for a long time. Water flow can be controlled automatically with almost any degree of accuracy in closed systems. One important factor rules against the use of this technology for surface irrigation – its high cost. There is no economic realism in installing an automated surface irrigation system that involves a large number of costly automatic valves. A system of this kind would be more costly than a fully pressurized one.

The earliest developments in automated surface irrigation mostly involved open canals. Many ingenious devices were developed for water control in lined and unlined canals. Several of the gates, weirs, and checks were designed to work in both lined and unlined canals, but practical experience strongly favors lined canals because they are not subject to erosion, washouts, and weed problems. An automated surface irrigation system can be expected to work satisfactorily only in conjunction with lined canals, particularly with those having cast-in-place concrete linings. But systems with lined irrigation canals may cost as much as systems with conveyance pipes of the same capacity. The closed system has many advantages. It is technically easy to control flows in and from a closed system, whereas it is difficult to set spiles into concrete-lined canal banks and to adjust surface outlets to produce uniform flows. Because an automated surface irrigation system is complex and must be designed and set up by an irrigation specialist, its cost is high.

Water distribution from low-pressure pipelines has economic and technical advantages over the open canal system. This is probably the reason for greater emphasis on this approach in recent years. Several promising low-cost valves have been developed that could make this method economically attractive. If these components are to be used they must be available at low cost, but to date manufacturers have been reluctant to start production. There is also a need for technical organizations that would point out to potential users the possibilities that exist with automated surface irrigation.

The automated surface irrigation installations that the author has observed in the field have been set up for field testing by developers of components. It seems that many "bugs" have to be eliminated from these systems before one can expect them to become popular with farmers.

Unless automated surface irrigation can be competitive with fully pressurized systems, farmers are not likely to be interested in it. When cost comparisons are made of the two systems, the expense of land grading, which is normally required for any surface irrigation method, should be included in the total cost of automated surface irrigation. In addition, sprinker manufacturers are well established, with their field-tested equipment offering strong competition to any other irrigation system.

The choice between one irrigation system and another is mainly based on economics. The system that can do the job at the least cost is usually chosen. This assumes that the important features, such as the operating labor requirement, reliability, and water distribution efficiency, meet the minimum requirements.

Farming, which involves so many physical, chemical, meteorological, and biological factors, is immensely more difficult to automate than, for example, a specific industrial process. It is open to debate whether agriculture has advanced sufficiently to be ready for remote-controlled farming.

Automation of some or all manipulations involved in irrigation would eliminate much hard and unnecessary labor. It is easy to automate mechanical operations but difficult to eliminate steps that require decisions and judgment. A good irrigator makes decisions and relies on his experience throughout the day. Man has used his ingenuity to overcome many of the problems he has faced. He is likely to continue to do this in developing automated surface irrigation.

SUMMARY

Surface irrigation by manual methods, because of its high labor requirement, is rapidly being replaced by automated sprinkler irrigation. Various gates, valves, dams, and weirs have been developed that, when used, enable a surface irrigation system to function automatically or by remote control. These components must be reliable, inexpensive, and simple to operate. Hardly any of the recently developed components are being manufactured for commercial use.

Automated equipment can reduce the labor requirement of the traditional surface irrigation. Further developmental work, field testing, and commercial production of automatic water control devices are necessary to make surface irrigation competitive with other more automatic systems of irrigation.

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