AUTOMATIC EQUIPMENT FOR SURFACE IRRIGATION

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Automatic and semi-automatic surface irrigation structures and systems are being developed to improve irrigation water management and conservation on the farm. Most mechanized structures may be classified as fully automatic or semiautomatic depending upon their method of operation. A fully automatic system operates without attention from the operator other than periodic inspections from one irrigation to the next. The need for irrigation and often the irrigation time periods, however, are still largely determined by the irrigator who usually has to turn water into the system. The semi-automatic system uses gates and checks which are normally tripped at a preset time by a mechanical timer or electrically. In addition to determining the need for irrigation, the irrigator also manually resets the structures or moves them from one location to another, or both, prior to each irrigation. With competition for available national water supplies increasing, some irrigation water users may be forced to use their water more efficiently. Automatic equipment provides a means of accomplishing this while at the

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same time saving labor. At a time when reliable farm help is difficult to obtain, and wage rates are increasing, an investment in automatic structures could be an economical alternative and may be more easily justified than in the past.

Surface flooding systems using basins, borders or contour ditches are easiest to automate since the field topography allows the entire stream of water to be distributed over the soil surface. When furrows are used, however, the irrigation stream must be uniformly divided into many small streams directed into individual furrows. This requires furrow flow regulating devices or controls in addition to check and turn-out structures.

Review of Automatic Irrigation Equipment Being Developed by Various Investigators

One of the objectives of this paper is to present a brief review of the various automatic irrigation structures and devices which are available or in a state of development and which may be expected to be produced commercially. For many years attempts have been made to achieve some degree of automation in irrigation and many devices have been built with some being patented. Most, however, have not been produced commercially or used to a large extent. Recently, however, because of critical water and labor conditions, automation has attracted many individual farmers and researchers to experiment with various devices. Curtis (4)* reports the use of an automatically released canvas dam which is built and used by some farmers in Idaho. A similar type is also being used in New Zealand (15). These are tripped by a conventional alarm clock and are used primarily with the border method

* Numbers in parenthesis refer to the appended references.

of irrigation. A border inlet gate is operated simultaneously with the release of the main canvas dam. The border inlet gate is usually a drop gate which, when released, falls by its own weight and stops the flow of water through an opening. It may be mounted and tripped in a variety of ways and has been used by farmers in this country and New Zealand for several years (14) (2).

A system recently developed in Wyoming (7) uses a drop gate in the supply ditch with a cable attached to a series of small individual rotating disc gates. These are fastened to the inlet end of outlet tubes or pipes in the side of the ditch. When the drop gate is released by a mechanical timer, the cable opens the outlets in the section of ditch immediately upstream and allows water to flow onto the field. Irrigation proceeds up the ditch in this manner with each drop gate closing in sequence and opening the outlet gates immediately preceding it.

An ingenious system in California (17) uses a sugar cube to trigger the termination of irrigation in a border. A spring loaded sensing device containing the sugar cube is located near the lower end of the field. When water dissolves the cube, a wire extending from the lower end of the field to the supply ditch trips a gate on the border turnout. The turnout from the ditch into the border is a conventional pipe fitted with a flap-type gate which closes when it is released. When the gate closes, a connecting wire opens the next gate downstream which, in turn is closed at the completion of irrigation by a sensing device at the end of the border.

Slow moving traveling dams which divert water continuously from an irrigation ditch have been used and one model was produced commercially. This type of equipment has not been widely used, however, because of inherent problems. A modification of this system which shows promise (5) uses a water-filled, balloon-type, drive-wheel to form the dam and to propel the machine. The combination drive-wheel and dam is formed by a water-filled rubber tube surrounding a fiberglass drum shaped to conform to the ditch.

Experimental self-propelled traveling siphons have been developed and tested in Wyoming (16) (3). These are used primarily for soils having high intake rates and with border methods of irrigation requiring large irrigation streams. A machine is supported in the ditch by pontoon assemblies and is propelled along the ditchbank by a water turbine located at the outlet end of large siphon tubes.

A system using radio controlled inflatable pneumatic valves for controlling the discharge into borders was developed by Haise and Kruse (9). This was discontinued in favor of an improved system using hydraulically controlled butterfly gates in farm lateral turnouts (10). Double-acting water pistons open and close butterfly gates which are installed in turnout pipes into the field. Three and four-way hydraulically controlled pilot valves are connected into the system to control both the butterfly gates and check structures in the main ditch. A sinking float sensing device located near the lower end of the field operates a pilot valve which terminates irrigation in a particular set of borders and directs water into the next set. Several borders are irrigated simultaneously with irrigation automatically moving sequentially downstream as each group of borders is irrigated. This system requires a source of water pressure and installation of plastic hydraulic lines along the ditch bank and to the sensing device in the field. The hydraulic pressure is obtained from a small waterwheel or gasoline engine driven pump.

A radio controlled system for border irrigation is being developed by Bowman at Montana State University (1). This system uses a moisture sensing device coupled with a portable radio transmitter located near the lower end of the border and a portable receiver at the upper end. A gate in the supply ditch is operated by a small battery powered DC electric motor which is actuated by a radio signal from the transmitter. A similar gate in the turnout operates in response to changes in the water level and closes automatically when the supply ditch gate opens at the end of an irrigation.

Fischbach et al (6), report the development of a rather elaborate automatic buried pipeline system with a reuse or pumpback system incorporated. An electric pump supplying water from a well or other source is activated when tensiometers installed in the field sense the need for irrigation. The main pump discharges into a buried pipeline from which water flows through risers to gated pipe on the surface. Rubber pneumatic valves control the discharge from the risers. An automatically resetting timeclock controls the length of irrigation after being preset by the operator. The reuse part of the overall system collects runoff water from the field in a small reservoir where it is pumped back into the system. The gated pipe openings are manually preset for each field to deliver the desired amount of water to each furrow. All operations are electrically controlled from several control panels.

A discharge regulating device for use with gated pipe or layflat tubing has been developed in Russia (21). With this device, it is reported to be possible to automatically regulate the discharge from small distribution tubes fastened to layflat tubing. Uniform discharge from all tubes is possible regardless of the topography or slope on which the tube is laid.

Automatic Irrigation Equipment Developed At The Snake River Conservation Research Center

Mechanical automatic structures being developed at the Research Center do not require an external power source for operation and include simple timer controlled structures. These are being tested in automatic cutback furrows, conventional furrows, graded border, basin and contour ditch systems. Practically all of the equipment described previously was developed for border or other surface flooding systems. This is understandable since these systems are much easier to automate than furrow systems. However, an automatic cutback furrow irrigation system developed at Oklahoma State University (8) was installed for evaluation when used with a timer controlled check dam developed at the Research Center.

Semi-Automatic Drawstring Check

This portable, lightweight check consists of a nylon reinforced butyl rubber dam supported in a metal frame designed to fit the cross-section of a lined ditch. The dam is supported in the frame by a plastic covered steel cable drawstring which is released by a mechanical timer at the end of an irrigation period. A commercial timer was redesigned by the manufacturer for use with automatic structures. It is fitted with an escapement release which is operated by a small float. This permits the check and timer to be reset anytime between irrigations. The timer does not operate until water enters the ditch immediately upstream from the check. When this occurs, the timer is released by the rising float and begins timing the irrigation period. This check is ideally suited for use in an automatic-cutback furrow irrigation system, Fig. 1. When the check is used with this system the number of acres one irrigator can manage may be increased ten to fifteen times while keeping runoff to a minimum.

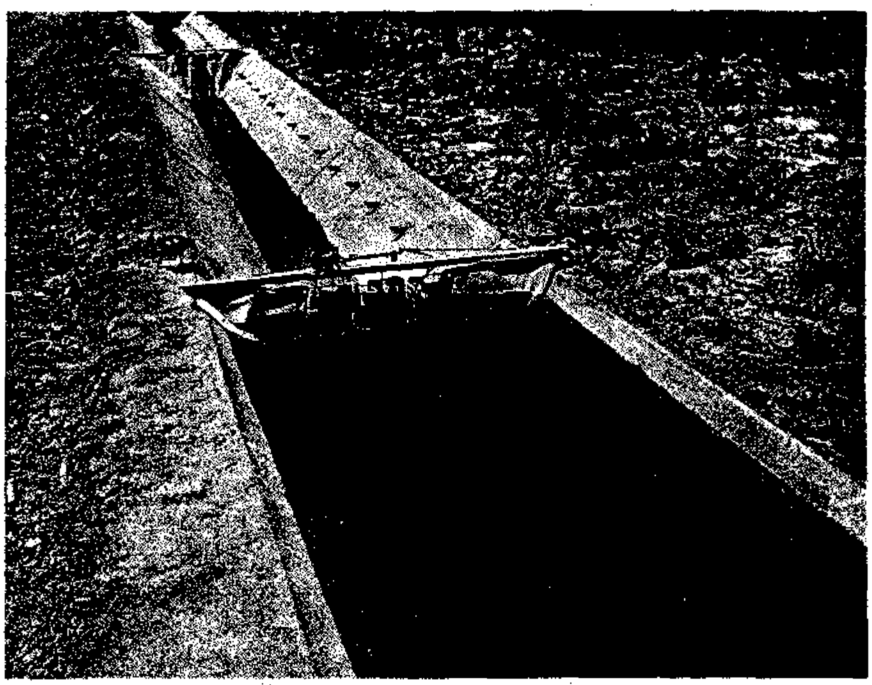

Fig. 1. Portable, semiautomatic drawstring check being used in an automatic-cutback furrow irrigation system.

The automatic-cutback furrow system consists of a lined ditch having an outlet tube for each furrow. The ditch is constructed in a series of bays with all furrow tubes in each bay installed at the same elevation. A semiautomatic check dam is placed at the end of each bay. When the check is released, the head on the furrow tubes in the bay immediately upstream is decreased resulting in a reduced or cutback secondary flow. At the same time, a high initial flow discharges into the furrows of the downstream section. Thus a high initial or primary flow in each furrow is followed by a reduced secondary flow. This results in an efficient irrigation with a minimum of runoff from the field. The experimental systems installed to date are equipped with furrow tubes made from standard pipe without an adjustment for flow rate. Experience during the past season, however, indicates that it may be desirable to equip the furrow tubes with adjustable gates so that the flow to individual furrows may be adjusted to compensate for variations in soil intake rates. Once adjusted the tubes should not require further attention during the remainder of a season.

The basic drawstring check for lined ditches may also be used in unlined ditches by providing sheetmetal cutoff walls instead of rubber seals on the edges of the frame. With the cutoff walls attached, the structure is installed in an unlined ditch at approximately a 45° angle much the same as in a lined ditch, Fig. 2.

Drop Gate

The drop gate mentioned earlier has been tested in both lined and unlined ditches as a companion device to other automatic structures. It is hinged at the top and in the open position is suspended over the top of the ditch. When released, it falls by its own weight and stops the flow of water in the ditch or through the turnout where it is placed. This timer-controlled gate is presently being used to irrigate sugar cane in Hawaii where in the past two years approximately 20,000 acres have been semiautomated.

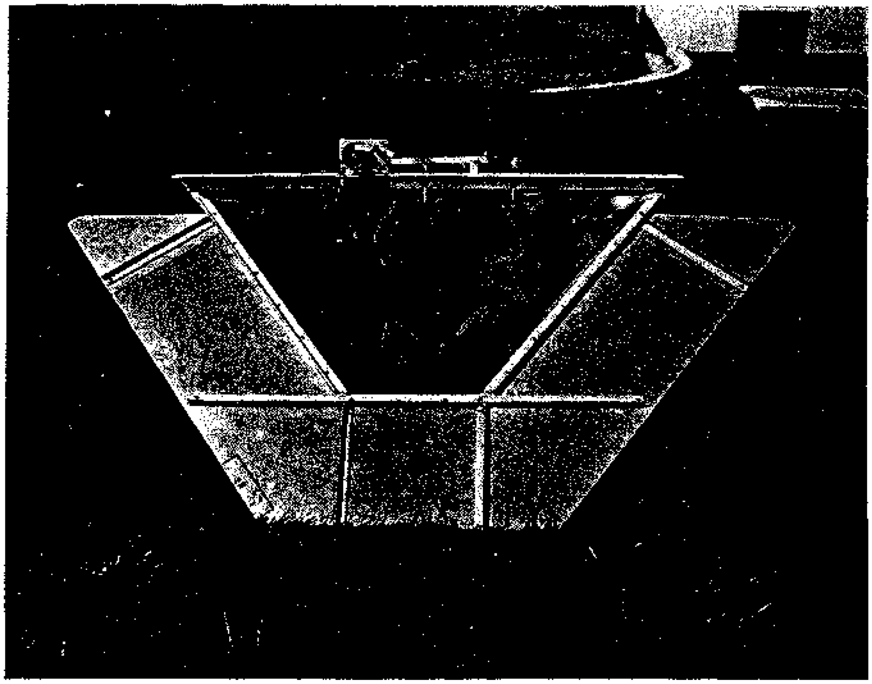

Fig. 2 Drawstring check with cutoff walls for use in an unlined ditch.

Pressure Gate

A gate using the principle of hydrostatic pressure distribution for tripping has been developed for use in both lined and unlined ditches, Fig. 3. It has a horizontal pivotal axis located at approximately one-third the water depth at which the gate opens. When the water level on the upstream side reaches a certain depth the gate opens automatically and remains open as long as water flows over it. The gate is fully automatic when fitted with a counterweight to return it to its normally closed position at the end of an irrigation. This check gate is ideally suited for use with companion structures where approximately 1-1/2-inches or more rise in the water surface are available for tripping.

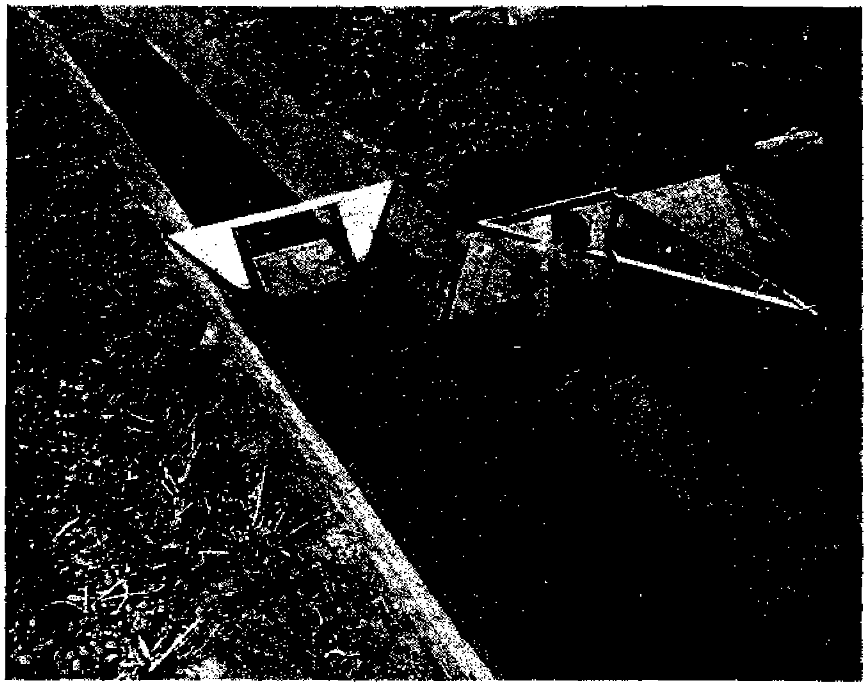

Fig. 3. Pressure gate (left) for lined ditches being used with a companion drop gate.

An economical, semi-automatic system may be obtained by using the pressure gate as a companion structure to the drop gate. The drop gate is placed in the turnout to the field and the pressure gate in the supply ditch. When the drop gate is released, the flow of water into the field ceases. This causes the water in the ditch to rise to the level required to trip the pressure gate. When the pressure gate opens, the water proceeds down the ditch to the next pair of gates where the operation is repeated. These gates may also be used to automatically divert water from one supply ditch to another.

The gates may be installed in the reverse order to irrigate from the downstream end of the ditch towards the upper end. In this system, the drop gate is installed in the supply ditch and the pressure gate in the field turnout. The field or border at the downstream end of the ditch is irrigated first. Irrigation of this section is terminated when the drop gate immediately upstream is released and stops the flow of water in the ditch. The water level above the drop gate rises until the pressure gate in the field turnout opens to admit water into the field. When irrigating in this manner, a safety feature is built into the system since only one irrigation set would be missed in case of a timer failure. The next structure upstream would operate at its scheduled time.

Sinking Float Border Gates

A sinking float border turnout gate was designed for use with the pressure gate to form a completely automatic irrigation system. The border gate shown in Fig. 4 is similar to a Tainter gate with a float

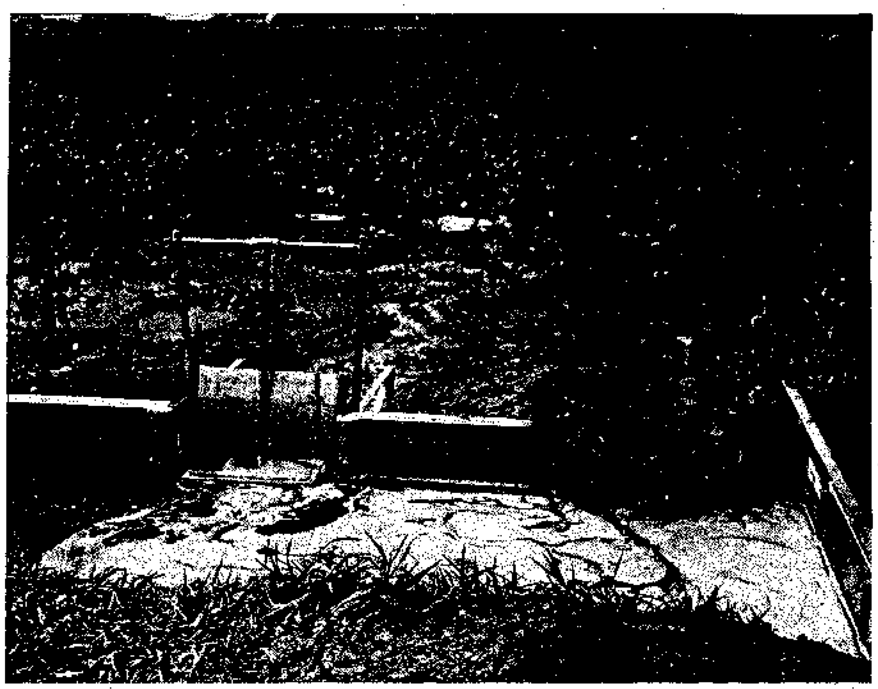

Fig. 4. Sinking float border turnout gate with a companion pressure gate (right) in an unlined ditch.

mounted on the front portion. The float is constructed with a water inlet at the bottom and a controlled air escape at the top. The float sinks at a rate controlled by the amount of air escaping. In operation, the float initially is buoyant and opens the gate when water is received in the ditch. The gate is counterbalanced such that the buoyant force from the float is sufficient to hold it open during irrigation. Irrigation is terminated when the float loses buoyancy and sinks, thus closing the gate. The rate at which water is allowed to enter the float is controlled by varying the size and length of a stainless steel hypodermic needle on the air-escape tube. A removable, plastic cover is placed over the needle for protection. The float on the border gate is constructed so that it loses buoyancy rapidly when the top of the float sinks to the water level in the ditch. This causes the gate to close rapidly. When the border gate closes, the water level in the ditch rises until the pressure gate in the supply ditch opens. Water is thus allowed to flow to the next pair of structures downstream where the sequence is repeated. When water is turned from the ditch after field irrigation is completed, the check gate returns to its normally closed position. The float on the border gate drains between irrigations so that it becomes automatically reset and ready for the next irrigation without attention from the farm operator. Operation of the structures referred to above is described in greater detail elsewhere (11), (12), (13).

Improved Efficiency with Automation

The use of improved automated irrigation structures and systems results in both labor and water savings. A semi-automatic system using level basins and alarm clocks to trip drop gates is reported to have an overall irrigation efficiency of 87% (14). In addition to increasing the irrigation efficiency, this system reduced labor requirements more than 80%. Preliminary data obtained at the Research Center indicate that an irrigation efficiency as high as 75 to 80% may be obtained from an automatic-cutback furrow system.

Labor performance data from several sources are given in the following tabulation for conventional irrigation systems and for those equipped with automatic structures:

Data Source and Irrigation System	Average Labor Requirements Per Acre Per Irrigation	Average Area Irrigated Per Hr.
	Hours	Acres
Manual Irrigation:		
Utah (19)		
880 ft. or more length of run	0.39	2.6
330-660 ft. length of run	.75	1.3
New Zealand (20)		
Border dyke with 8 cfs flow	.5	2.0
Hawaii (18) Sugar Cane		
Hilly terrain, steep slopes	.74	1.4
Level-level ditch system, mild slopes	.42	2.3
With Automatic Equipment:		
Automatic-cutback furrow irrigation system w/portable semi-automatic check dam (Research Center and Colorado installations)	.029-.04	25-35
New Zealand		
Automatic border dyke with 8 cfs flow	.028	36
Nevada (14)		
Drop gates and level basins	.028	36
Hawaii		
Hilly terrain, steep slopes	.35	2.8
Level-level ditch system, mild slopes	0.14	7.1

These data are indicative of the labor savings which may result from the use of automated surface irrigation equipment. Data from the Utah study are indicative of the irrigation requirements in the United States for good surface systems using concrete turnouts and headgates. The data are an average for both lined and unlined ditches. For systems which do not have permanent structures and which are not well designed or maintained, the labor requirements will be somewhat greater than shown. The labor requirement for the automatic-cutback furrow system is slightly greater than for the New Zealand and Nevada systems because the check dams were portable. The increased labor represents that required to move the portable check dams from one location to another. If sufficient checks were used so that they could remain in place, or if permanent automatic structures were used, labor requirements should be comparable to those reported for New Zealand and Nevada where the structures were permanently set in place.

Work is being conducted in some Soviet associated countries to reduce furrow irrigation labor requirements. A system has been developed for use in East Germany and Bulgaria (22) for automatically priming siphon tubes. Information pertaining to the system is somewhat meager but the labor statistics reported are indicative of the increased performance which may result from automating or partially automating an irrigation system. The average productivity of an irrigator in these countries is reported to be approximately from 0.4 to 0.6 hectare (1 to 1-1/2 acres) per shift with furrow irrigation on uneven ground using a hoe. On fairly level land and long runs the productivity is approximately 2-1/2 to 3-1/2 hectare (6 to 9 acres) per shift. This is approximately one-half the labor performance in the U.S.A. using siphon tubes in lined ditches. By using automation in varying degrees, the labor performance was increased to 10 to 15 hectares (25 to 37 acres) per shift.

In addition to the labor and water savings resulting from the use of automated surface irrigation equipment, better water management can often result in increased yields. For example, irrigation efficiency of mountain meadow systems is normally very low. Some of the timer controlled structures developed at the Research Center were field tested on a mountain meadow field in Wyoming. The study involved the irrigation of two adjacent fields in which one field was irrigated in the conventional manner with water applied almost continuously throughout the irrigation season. The other field was equipped with automatic checks and good irrigation practice followed. Under the improved water management practice, the hay yield from the one crop normally harvested in that area was one-half to one ton per acre greater than on the field irrigated by conventional practice.

Future Outlook

An irrigation superintendent on a Hawaiian sugar plantation stated, "Automation or mechanization is causing a revolution in Hawaiian irrigation." This same revolution will undoubtedly reach the mainland. Automation of surface irrigation at present is somewhat limited by the availability of commercial equipment. With the various systems under development, irrigation equipment manufacturers most certainly will be adding automatic components to their present equipment line.

With the development of mechanized equipment well underway, more attention needs to be given to developing field layout requirements and design criteria.

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