Moisture-activated Kink Valves for the Hose-fed irrigation of individual trees, shrubs and vines.

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Abstract. *This paper explores the benefits of employing moisture-activated Kink Valves for remote irrigation, over conventional pinch valves and stopcock (end stop) valves. This new family of valves is manufactured from a combination of moisture-absorbing thermoplastic elastomers (TPE's) in a configuration that results in a bi-stable, mechanically-advantaged geometry. This enables the valve to 'flip' from a dry 'straight open-bore' state to a wetted 'kinked-closed' state and vice versa. These valves do not need filtered water, they operate from only inches of water-head and are self-purging. Data will be presented confirming their performance, energy and cost-saving benefits. Published International Patent Document WO 2008/068496 reveals how this is achieved and how Kink Valves provide an opportunity to expand 'Drylands' agriculture, using a minimum of irrigation water and without the need for electricity. Earlier patents for moisture-activated valves will be illustrated to show how advances in one industry make possible developments in another.*

Keywords. Moisture-activated irrigation valves, low head hose-fed irrigation for trees, shrubs and vines, kink valves, pinch valves, stopcock valves, earlier patents, commercial designs, moisture-swelling materials, some essential elements for a bi-stable bi-polymer valve, optimising hose system layout from a centrally positioned low head water supply tank, saving electricity, water and labor.

Introduction

It is felt that in remote low rainfall areas and where there is no electricity, horticulturalists could benefit from a simple design of water control valve to regulate the individual hose-fed outflows to widely spaced trees, shrubs and vines. Such a valve would have to be easily fitted to the open end of each hose lateral in a distribution system and rely solely for its operation on variations in local moisture. Given a practical and commercially viable solution Designers would be well placed then to provide horticulturalists with simplified 'on demand' irrigation systems on any scale, so reducing the costs of food production – this is our goal.

Table of Contents – in association with an animated Power Point® Presentation

Past experiences

Limited always by the *materials of their time* a great many people have devoted their energies to designing and producing moisture-activated valves. In the past there have been a number of very significant design proposals and some of these have reached the production stage and achieved success in niche applications. I personally owe a great deal, and empathize strongly with these pioneers, for signposting the way and demonstrating the scope of the two favoured design principles namely, the pinch valve and the stopcock. To date though, neither of these has been adopted for the large scale commercial growing of trees, shrubs and vines.

A new approach
With the very *latest materials* and a fresh approach it might be possible now to revisit the original 'constraints and opportunities' to establish a third basic design principle. For example, where previously only one moisture-swelling material was employed as the prime mover, it might be possible now to employ a combination of polymers to mimic some of the properties of the bi-metal thermostat.

This would introduce the prospect of serious animation to valve design, providing it with a snap open and close action, rather than the traditional slow hydraulic opening and closing. Such a valve would be bi-stable and perhaps exhibit different characteristics from pinch valve and stopcock designs.

With this in mind we have combined together up to three polymers (thermoplastic elastomers) in a special geometry to produce what we now call a moisture-activated Kink Valve. This bi-stable design is so radically different from earlier valves that we feel it represents a new, third design principle for the irrigation industry.

The future
Our work is not finished, as we still need to employ large numbers of these valves in the field, to better understand the size of the gains from simplifying hose-fed irrigation and reducing year on year operating costs. We are confident that these will be shown to be attractive to growers and sustainable for the long term, as energy costs rise and water supplies become more critical.

The evidence to date
The following text and illustrations are based around a Power Point® presentation of twenty slides some of which contain video clips and animations. They are reproduced here in a simplified form, starting at slide 3 in the series and concluding at slide 19:

Slide 3 What options do we have?

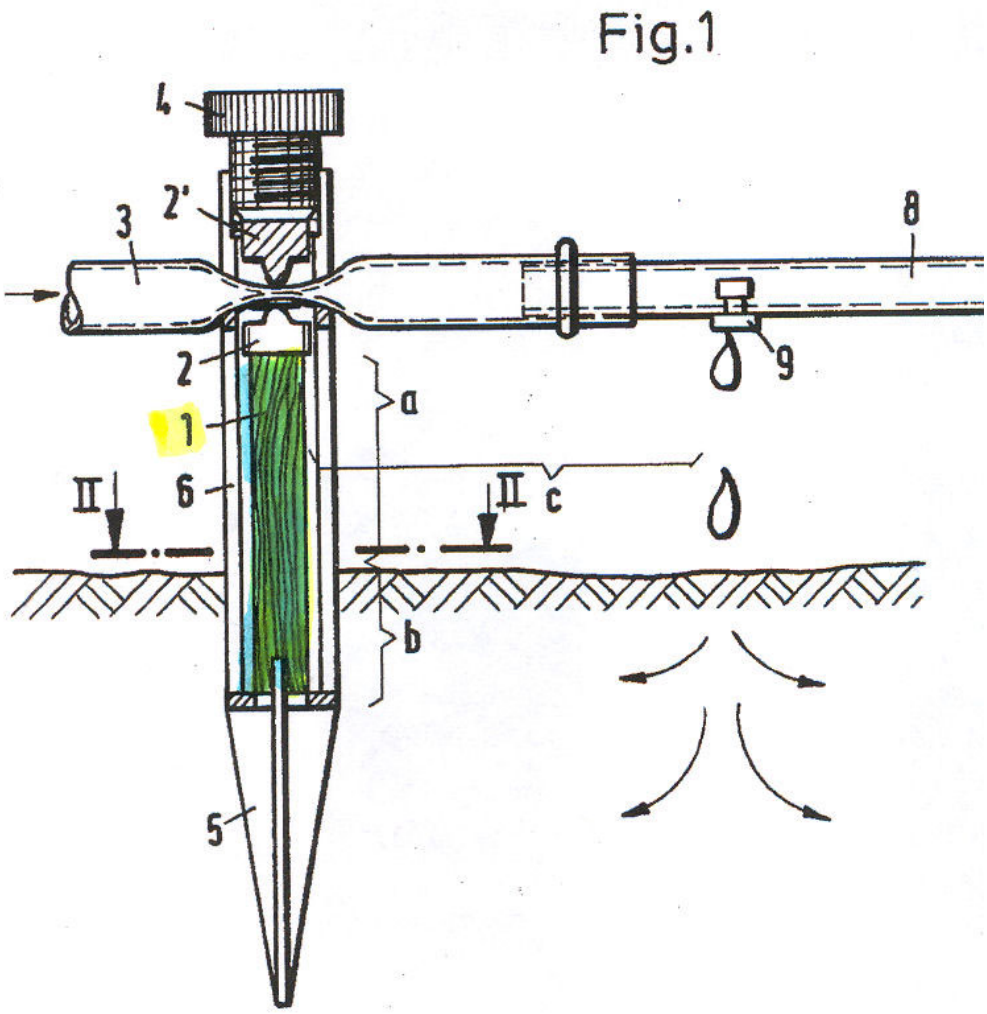
> For gravity-fed hose systems, individual outflows are controlled by one of two classic methods namely, moisture-activated, Pinch valves and Stopcocks. *Pressure-fed Dripper valves are not within the scope of this paper.* Kink Valves offer a third option perhaps with different benefits? But what has already been invented and what is available to buy?

*The **IP** year dates inside the brackets refer to the year that the **Intellectual Property** was filed as a patent application.*

Slide 4 The Patent Archives reveal (1): Pinch Valves: Top view

Irrigation valve device (IP 1978) Gerhard Beckmann, Patent US 4,214,701.

"The water swellable member 1 could be: wood – spruce, fir or pine, or a polymer – Polyurethane Gel."



This 'general' configuration of a pinch valve which is spiked into the soil, appears many times in the Patent Archives and has been used ever since vulcanised rubber was first used to make hose pipes and tubing.

Slide 4
Lower view

Irristat™ (IP 1978) Leonard Ornstein, Patent US 4,182,357.

"A water swellable hydrogel, for example based upon polyacrylamide, polyvinyl alcohol, Formulations, etc."

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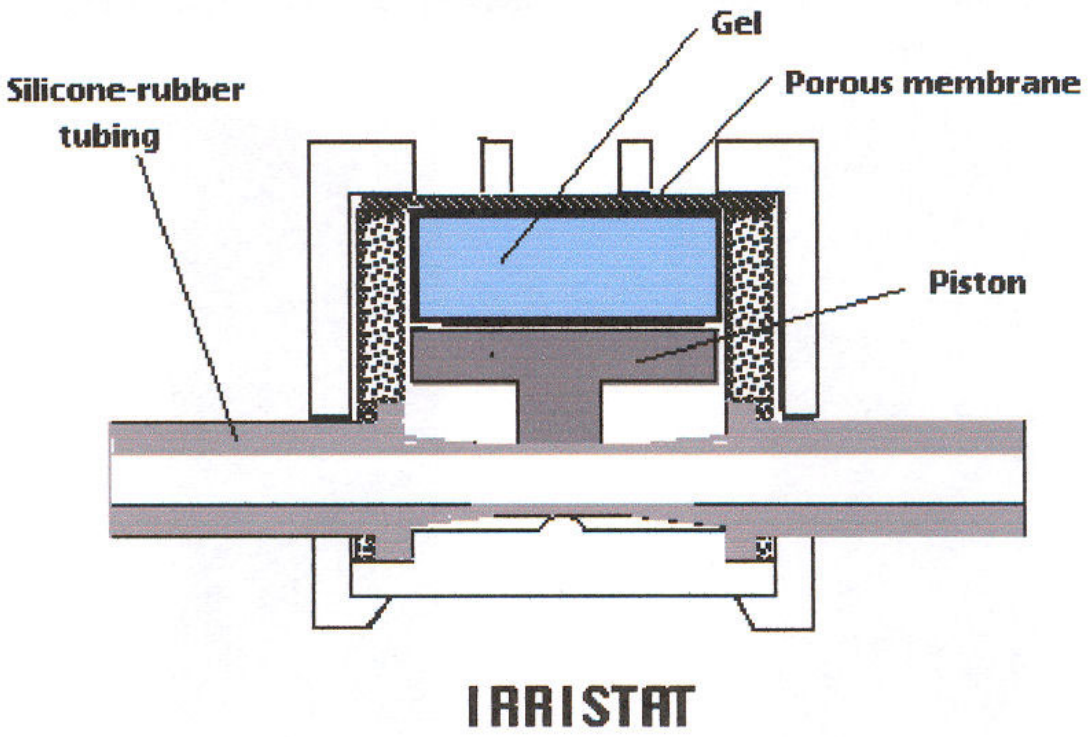

The Irristat™ valve was used extensively in the field over many seasons and geared to controlling the water supply to individual fruit trees, etc. Preferably the product is sited below soil level.

Slide 5 The Patent Archives reveal (2): Stopcocks (end stop) valves: Top view

Moisture-activated valve (IP 1985) Gant, Patent US 4,696,319.

"Bentonite hydrophilic expandable material."

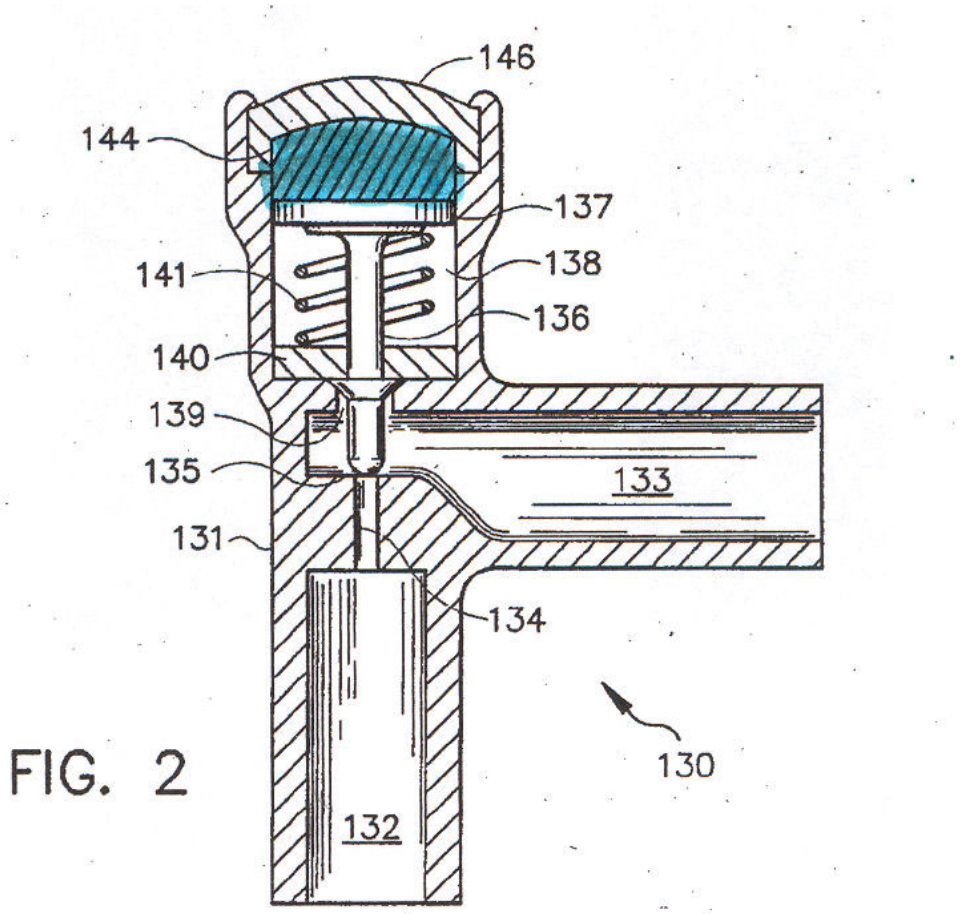

FIG. 2

This is an example of a stopcock type of valve, where the moisture swelling member 144 (shaded blue), working against a spring 141, is exposed to moisture entering and leaving through the top porous membrane 146 and generating hydraulic movement at the end stop 135. It is necessary for this type of valve to be in intimate contact with the soil.

Slide 5 cont'd
Lower view

SmartValve® (IP 1988) Graham et al. Patent US 5,382,270.

"Polyethylene oxide hydrogel."

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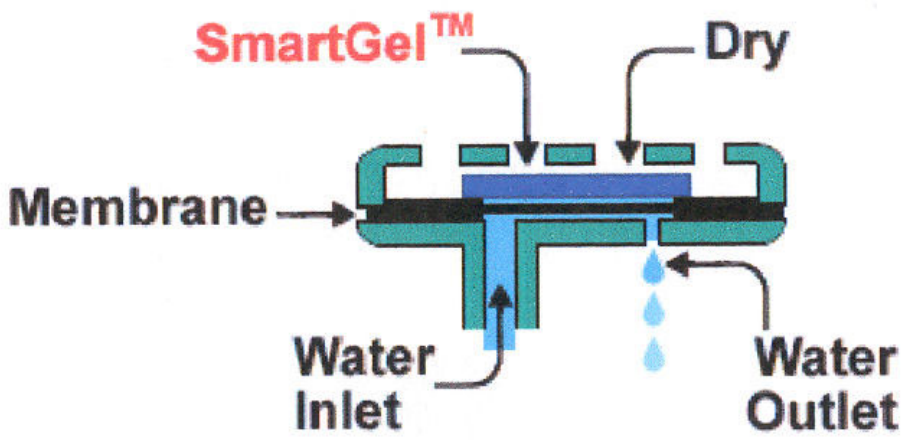
Web: www.smart-tech.uk.com
Smart Tech Ltd, United Kingdom.



This type of stopcock responds to being in intimate contact with the soil or growing medium.

Slide 6 The Market reveals:
Top view

SmartValve® Stopcock (IP 1988)
A moisture swelling Smartgel™ disc element which wets-up to press on a membrane to stop the flow of water through the valve.

slide 6 top view continued,

“particularly preferred is the use of a cross-linked, partially crystalline polyethylene oxide Hydrogel.”

Web: www.smart-tech.uk.com
Smart Tech Ltd, United Kingdom.

Side/ front view

Rear/ side view

The activating moisture enters and leaves through the four apertures on the front face. The irrigation water from a push-on hose lateral, enters down the tubular stem, and when the valve is dry, passes across the internal membrane and exits into the soil through the recessed hole, arrowed (yellow).

It is worth noting at this point that the advent of new moisture swelling polymers has given the designer a new degree of freedom, which was not possible before with the limited-life, moisture swelling wood members and clay compounds.

slide 6 continued over page,

Slide 6 cont'd
Lower view

AquaSmart™ Stopcock (IP 1994)

A moisture swelling polymer (blue) takes the form of a piston and wets-up to stop the flow of water through the valve.

"Polyether block amide."

Moss Products Pty. Ltd, Australia
Web: www.mossproducts.com.au

This product is spiked into the soil so that the blue swelling polymer is in intimate contact with the soil or growing medium. The irrigation water enters the tubular stem on the left side, to which is attached a hose, and passes through the hole (arrowed yellow in the cut away view). Still inside the valve body the water is forced upwards and into the swivelling cowl which directs it back down again and onto the soil. By this means the valve can be adjusted to increase or decrease its delivery of water over time.

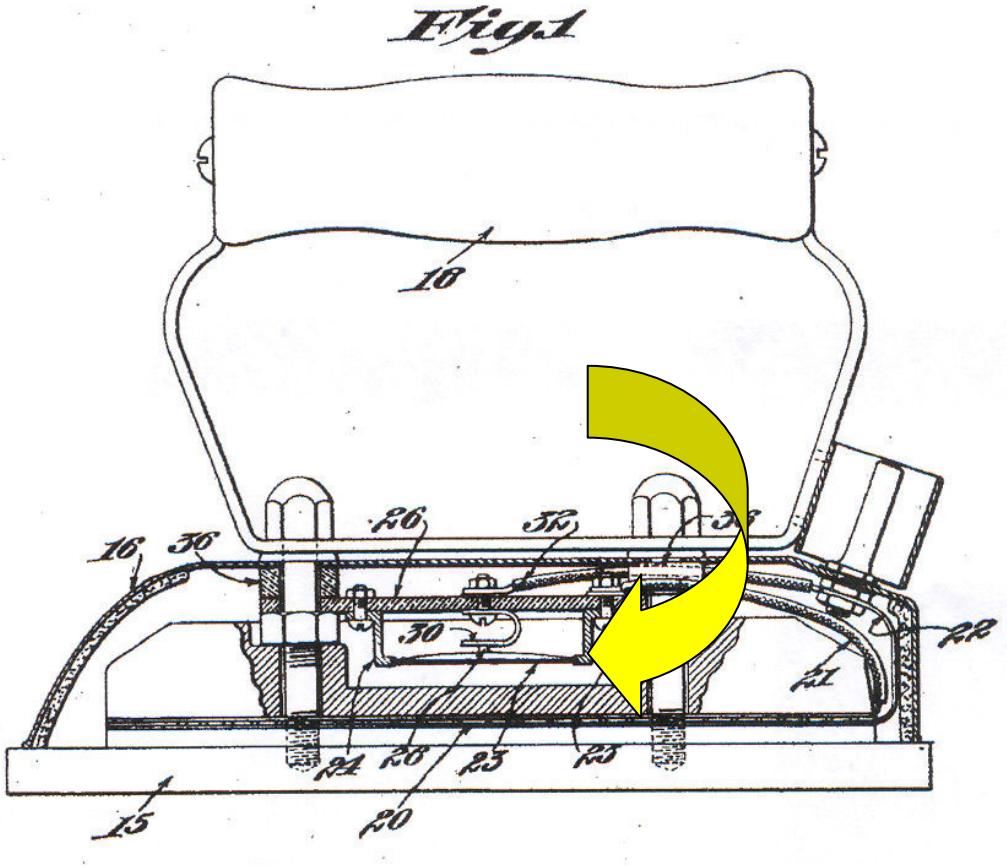
Slide 7 Moisture-activated Kink Valve.

If we could make a Kink Valve using not just one but two or more thermoplastic elastomers (TPE's) with different moisture swelling properties, we might be able to make the Water Industry's equivalent of the bi-metal thermostat?

Slide 8 Elements of a bi-metal thermostat.

On 8th April 1921 John A Spencer of Massachusetts filed a patent application for a bi-metal thermostat device: Patent US 1,448,240.

*"to which is imparted a **sudden and rapid** movement when a substantially predetermined temperature is reached."*



The two special features of this switch (shown here in a smoothing iron) were that it was **able to convert the slow curling action** of the bi-metal element **into a sudden and rapid movement** by way of its special geometry to create a very positive bi-stable switching action – this minimised the arcing and burning of the contacts that was a normal occurrence when the circuit was made and broken repeatedly, to control the ironing temperature. At the time this was a very significant step forward for the Electrical Industry. Billions of these types of switch are in daily use around the world.

Slide 9 Moisture-activated, bi-polymer Kink Valve.

To make this new type of water ‘switch’ we need to accomplish the two steps as follows:

1. Initiate a curling action similar to that of the thermostat, but with moisture and not with heat, and

2. control the movement within a special geometry to create a mechanical advantage, to produce a bi-stable flip/ flop action.

Preferably the new valve will have a straight-through open bore with no restrictions to keep hose sizes to a minimum. The valve must also close positively and open again fully – to prevent blockages and leakage, i.e. it must be self-purging.

Slide 10 Step 1: Make a moisture-activated, bi-polymer strip element.

Two TPE’s with very different moisture swelling properties have been bonded together.

Underside view

Side view

This is a simple and effective demonstration.

Slide 11 Step 1: continued

From a dry state submerge the bi-polymer strip element in water and this is what happens after approximately 2 hours.

Side view

This reproduces the first condition – the curling action. How good is this material combination, what happens if we leave it in the water overnight?

Slide 12 Step 1: continued.

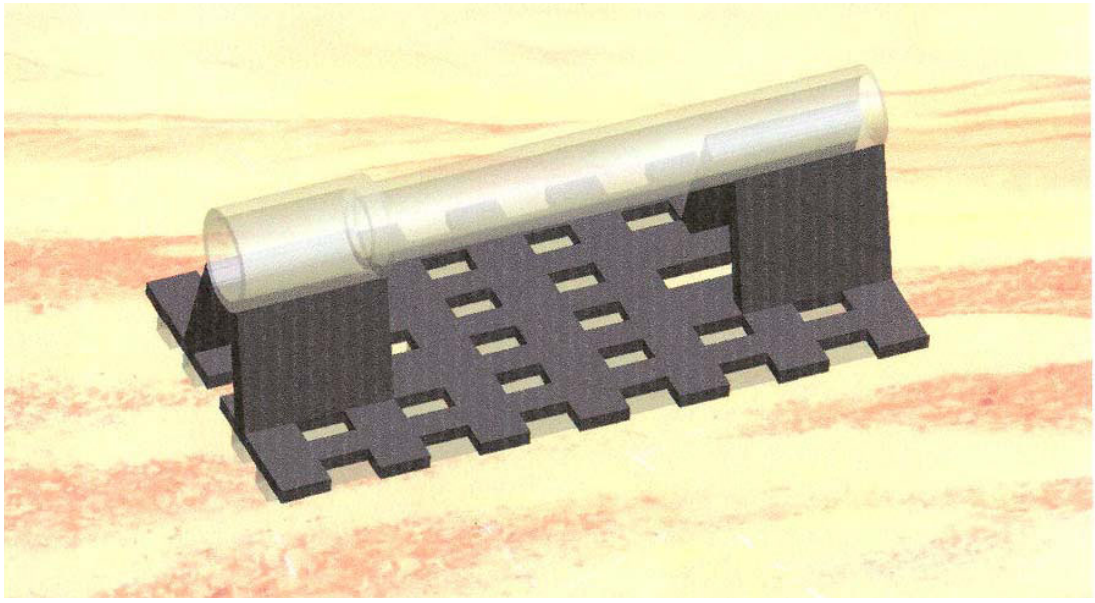
Sample strip element following an overnight soaking.

slide 12 continued

It is evident that this material combination has a very special property which we can put to good use. Note, it is only necessary to use a part of this potential for curling to create the basis for a kink valve.

Slide 13 The Moisture-activated Kink Valve features

There is a ten second animated E-Drawing on this slide which shows how the various features of the (2” long) Kink Valve have evolved.



1. At the base of the valve shown and underneath the dark waffle plate (perforated) there is a spider shaped web of high moisture-swelling polymer material.

2. The high moisture-swelling material is bonded to the underside of the dark waffle plate which is a low moisture-swelling polymer material, and in this example very elastic.

3. Four standoffs rise up from the waffle plate to form a cradle for the irrigation tube.

4. The irrigation tube is a very low moisture swelling polymer with the ability to kink repeatedly – in bore sizes: 5/32” (4 mm), 1/4” (6 mm) & 5/16” (8 mm).

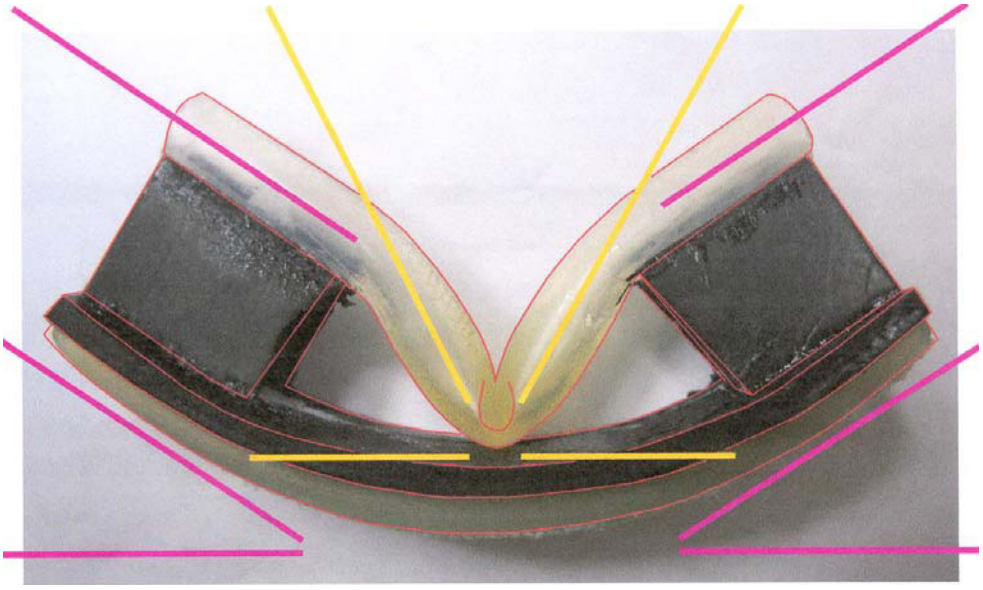
Providing water flows from, 1/2 gal. (2 litres) – 14 gal. (50 litres) per hour, and with water heads from as little as 20” (0.5 metre).

When these different materials are brought together in this special geometry and in a dry state the device can be connected to the free and open end of a hose lateral. In this dry state the valve will allow water to pass freely through its full open bore for as long as the valve remains dry and the water supply is available. For example from a supply tank providing anything from a two foot to a ten foot head of water. If at some point the valve is wetted up on the outside the subsequent swelling and stretching of the polymers will cause the valve base to curl inwards on itself to a point where the irrigation tube will suddenly collapse to form a kink. It is this action which closes off the passage of water.

Once the valve has had some time to dry out again and partially de-curl, there will come a point when the kink suddenly disappears and the water passage is opened up again to resume watering.

Slide 14 Step 2: Create the special geometry - the Mechanical Advantage.

The dramatic formation of a kink described above in slide 13 is shown here.



Note, the acute kink formed in the tube (yellow guide lines) as a direct consequence of the gentle curling of the high moisture swelling base element (magenta guide lines).

Slide 15 The Kink Valve in operation

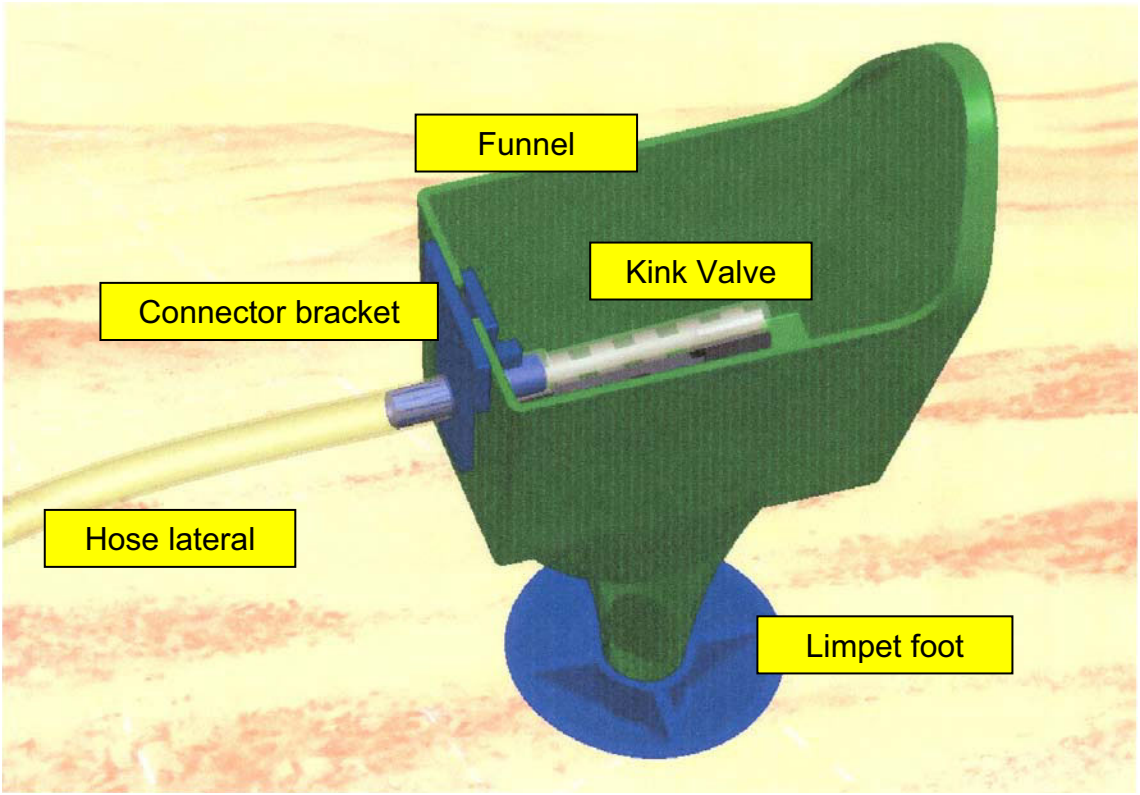
This is a twenty second video clip of the Kink Valve in operation, snapping shut and closing off the water flow.

Open – dry state

Closed – wet state

Slide 16 Kink Valve funnel assembly for field use.

This slide is a ten second animated E-Drawing showing the assembly of the Kink valve, its connector bracket, funnel and limpet foot coming together and attaching to the free and open end of a hose lateral.



slide 16 cont'd

The components are described as follows:

- **Funnel** – this is used as a housing and drainage point for the irrigation water.
- **Kink Valve** – this is used to switch the water on and off.
- **Connector bracket** – this is used to join the lateral hose to the Kink Valve and serves also to secure the sub-assembly to the funnel housing.
- **Limpet foot** – this acts as a ground anchor to prevent rodents and birds from uprooting the whole assembly.

In field use the funnel is partially buried with only the top one inch visible above ground level. The funnel has options for up to three drain holes, to cater for different watering needs.

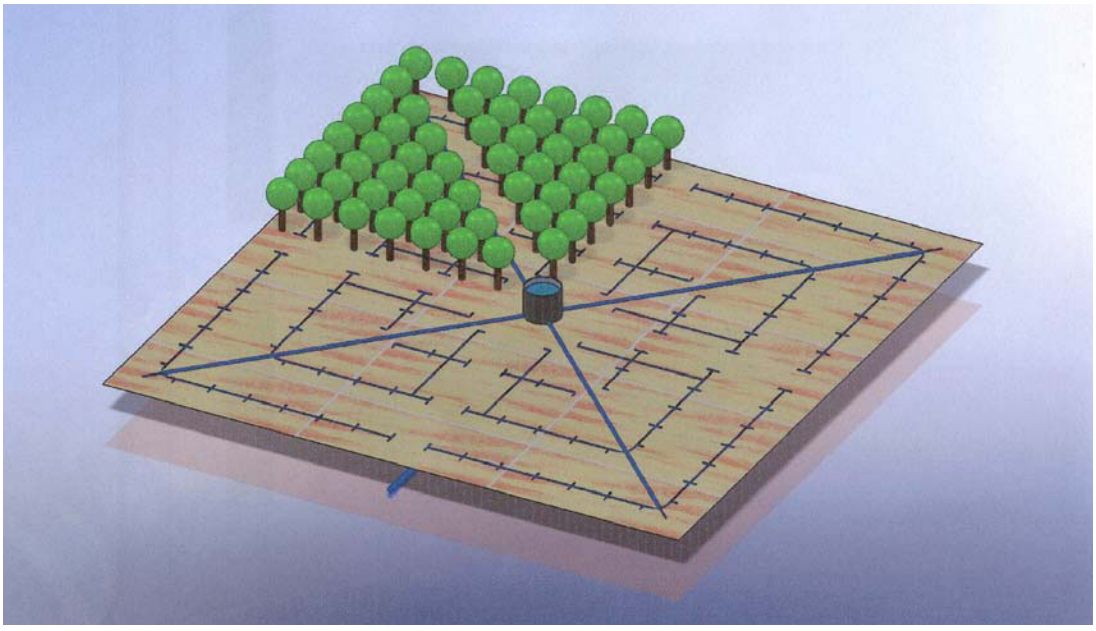
Slide 17 Kink Valve funnel assembly operating in the field.

This is a twenty second video showing the Kink Valve delivering water to a tree and then snapping closed when the watering is completed.

Slide 18 **The potential for gains employing moisture-activated irrigation valves in gravity fed hose distribution systems.**

- ❖ Costs less - simpler and smaller hoses
- ❖ Visible – not buried underground
- ❖ No electric power needed
- ❖ No pumping
- ❖ No pressurized filtration
- ❖ Optimum water usage
- ❖ Self purging
- ❖ Less maintenance
- ❖ Will fertigate.

Slide 19 **This slide is a twenty second animated E-Drawing of a citrus grove describing a tank-fed hose layout and its operation.**



Conclusion

A study of the patent archives and the commercial market confirms a long-standing and continuing interest in moisture-activated valves for controlling the individual outflows of hose-fed irrigation systems. This is particularly relevant where hose laterals are widely spaced for example in the cultivation of food producing trees, shrubs and vines.

There have been significant advances in the materials available for these special valves which traditionally fall into two classes of operation namely, pinch valves and stopcocks. New polymer based materials are providing Designers with the opportunity to refine existing configurations and to consider radical new designs based on Technology Transfer from other industries.

The new moisture-activated Kink Valves currently under development, exhibit animated properties similar to those of the electric thermostat. This adds a new dynamic to water-control valve design.

It is likely, in the very near future, that moisture-activated valves will come under the spotlight as growers seek solutions to overcome water and electricity shortages in the face of growing pressure to increase food production on ever more marginal land. It is hoped that the Irrigation industry will be well placed to supply a useful range of moisture-activated valves.

Acknowledgements

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2. AquaSmart™ is a Trade Mark of Moss Products Pty. Ltd, Australia. Further details available from web address: http://www.mossproducts.com.au

3. Irristat™ is a Trade Mark and invention of Leonard Ornstein of the United States of America. Further details available from web address: http://www.pipeline.com

4. SmartValve® is a Trade Mark of Smart Tech Ltd, Scotland, United Kingdom. The SmartValve is an invention by; Professor Neil B. Graham, Robert A. K.

Szmidt and Ralph C. Kirkwood all of Scotland, United Kingdom. Further details available from web address: http://www.smart-tech.uk.com

5. Kink Valve™ is the generic name for the Liquid Lever® irrigation valve. Rights reside with the charitable status company: Grow More Food – A limited company registered in England, United Kingdom, Reg. No. 6652992. Further details available from web address: http://growmorefood.org

6. Rights to use the Kink Valve technology are assigned to the company Liquid Lever Solutions Ltd – registered in England, United Kingdom, Reg. No. 6533540. Further details available from web address: http://growmorefood.org

7. The Intellectual Property relating to the Kink Valve is protected and published in the following International Patent Document: WO 2008/068496 A1.

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