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A Zippered-Pipe Principle for Irrigation Water Supply

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INTRODUCTION

A few years ago the Hawaii Agricultural Experiment Station received federal research money via the Regional Research Committee of the Western States for work on fundamental aspects of sprinkler irrigation. This opportunity was utilized for studying certain fundamental aspects of irrigating by means of moving suspended pipe. The aspect which is discussed here is that of supplying water to a moving pipeline.

At present two systems of suspended, moving irrigation pipe are in field use. In one, aluminum pipe is mounted at intervals on wheels, the pipe being at wheel-axle height or about 3 feet above the ground surface. This wheel-mounted pipe, up to 1200 feet in length, can be moved perpendicularly to its long axis by a tractive unit at the middle of the line. At present, water is supplied by attaching the pipeline to different hydrants by hand or by changing the position of a pump supplying the line. This system is mainly used for pasture irrigation.

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In another system, pipe is cantilevered, up to 150 feet, on each side of a central tractor. The cantilevered sprinkler machines are used for irrigating pineapple on the islands of Molokai and Lanai and they have recently been introduced in other places too. On relatively flat land, where grade control is possible, the tractor pumps water from a ditch through a flattened foot valve. On steeper land, where the desired ditch grade cannot be attained, water is supplied by coiling and uncoiling rubber tubing attached to a fixed hydrant. The huge coils on the cantilevered machines could be eliminated and an opportunity could also be created to supply moving wheel-mounted pipe with water, if it were possible to develop a pipe with a moving discharge outlet, as suggested in figure 1. A zippered pipe, now used on aircraft carriers for catapulting planes into the air (U. S. Navy, 1957) , has been suggested for this purpose. This paper reports on the outcome of a model study of this possibility.

PROCEDURE AND RESULTS

A Goodrich zipper No. double 450 was mounted, by vulcanizing, onto the two edges (along the long axis) of a sheet of non-reinforced, extruded butyl rubber with molded surface. The sheet had a thickness of 3/16 inch and was 6 feet long. On closing the zipper the sheet formed a tube, 6 feet long. Both ends of this tubing were sealed by plates and, by adding internal seals, the zippered-pipe section could be subjected to hydrostatic pressure. The test set-up allowed only 3 feet of head to be applied, and at this pressure the zipper proved watertight. The manufacturer's data show that the zipper has a crosswise strength of 225 p.s.i. (pounds per square inch) , and a lengthwise strength of 250 p.s.i. As the zipper has been designed for airtight sealing of aircraft cabinets, and considering also the presence of a rubber overlapping flap at the inside of the zipper, it can be assumed that the zipper is watertight at field pressures normally encountered in irrigation pipe.

This zipper has two sliders; each slider can be placed in any position with respect to the other, so that an opening of any size can be made any place along the length of the tubing (figure 1). By means of four wires, the two zippers are opened or closed on moving the discharge outlet. These wires are attached at one end to the outlet and at the other end to the sliders, (figures 2 and 3). Two wires are attached to each slider; one to the upper surface and one to the lower surface. As the discharge outlet is moved along the pipe, the zipper opens ahead of it and closes behind.

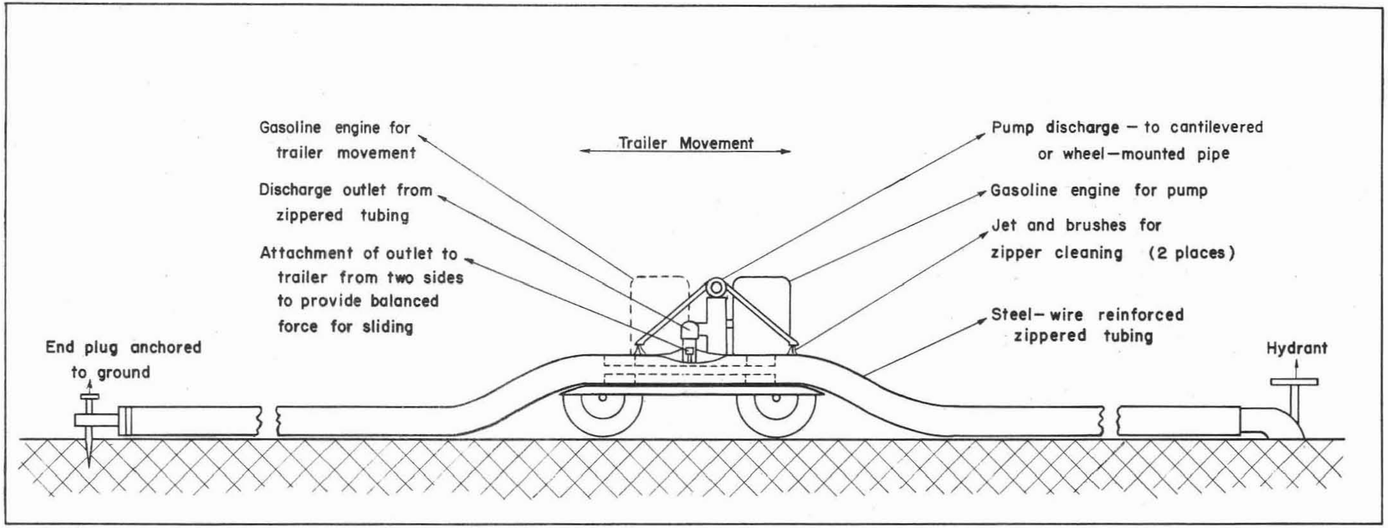

FIGURE 1. Trailer-mounted pump for water supply from zippered pipe to moving cantilevered or wheel-mounted irrigation pipe. Note that discharge outlet of zippered pipe is fixed to trailer and that tubing moves past it on moving the trailer.

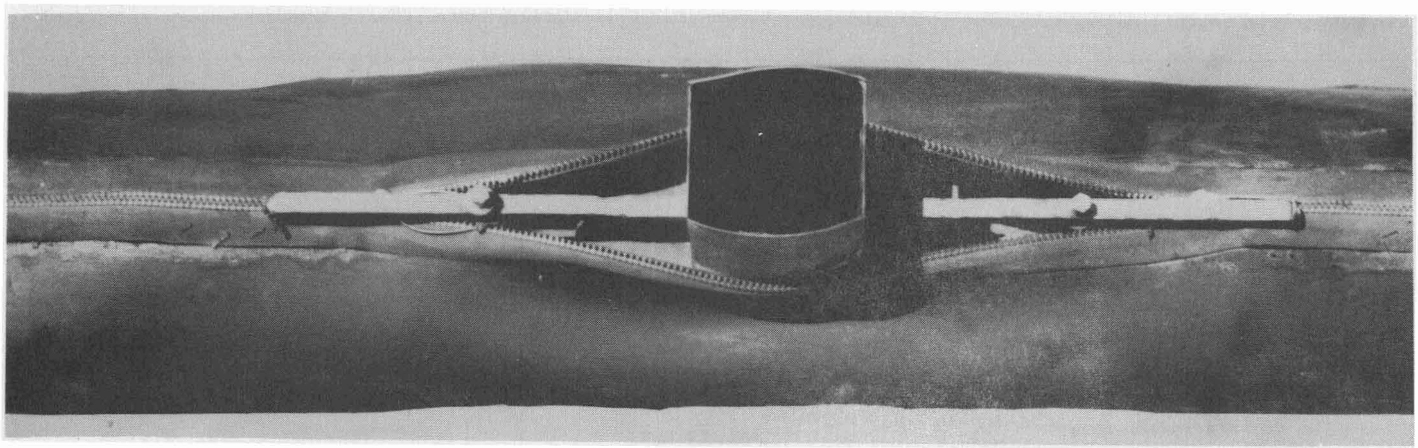

FIGURE 2. Model of zippered pipe. Note opening for accommodating moving discharge outlet and metal bars with wires connecting outlet to sliders on zipper. There is a slider on each side of the discharge outlet.

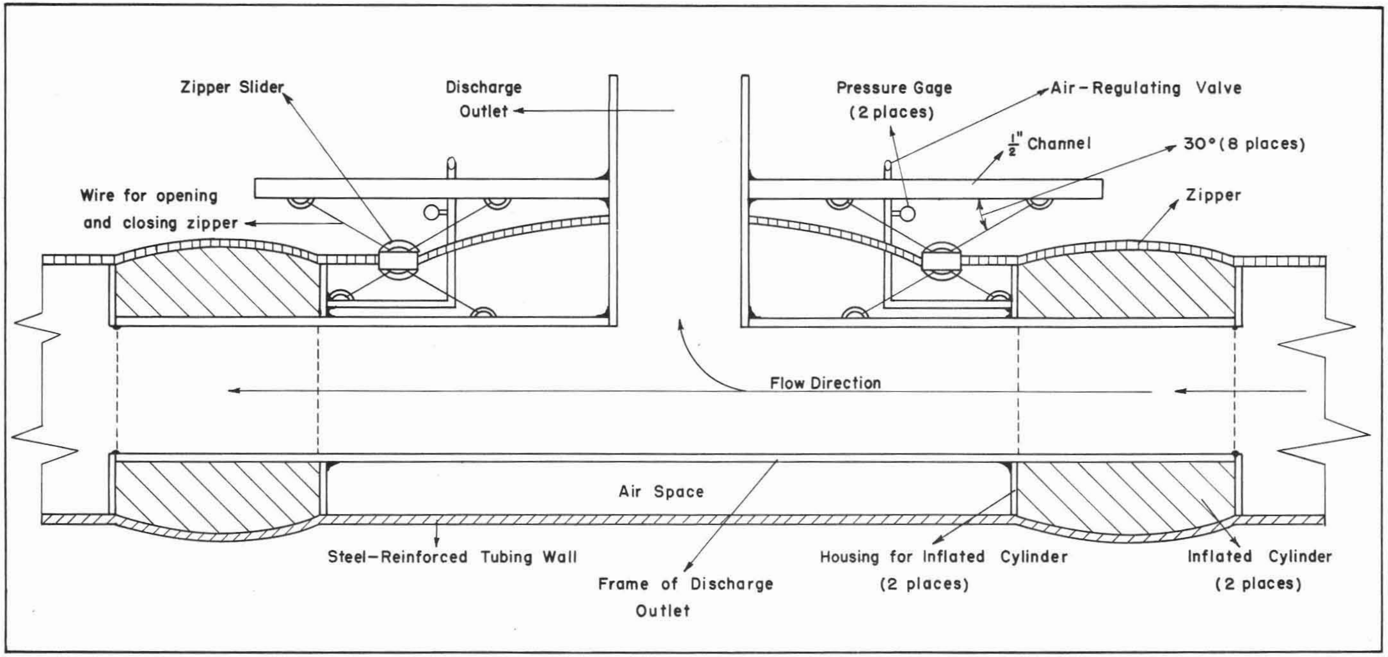

FIGURE 3. Cross section through discharge outlet of zippered pipe. Note position of inflatable cylinders and slider attachment at upper and lower surface of zipper. Zipper is opened at right-hand side and closed at left-hand side as the discharge outlet moves to the right, and vice versa.

The discharge outlet is thus located within an opening in the tubing, but within this opening water is discharged through the outlet only. A satisfactory functioning of the principle of a moving outlet is thus dependent on a waterseal at both the upstream and the downstream end of the outlet. In the 6-foot-long model, an attempt was made to provide such a seal by moving the tubing wall a short distance away from the outlet between an interior, hollow fiberglass cylinder and an exterior, wooden cylinder. Also, in a separate experiment (figure 4) , the tubing wall was moved between an exterior metal ring with ball bearings embedded at its interior periphery and an opposite (interior) metal cylinder. In both of these attempts, the force required to move the tubing past the seal proved excessive. On using an exterior and an interior cylinder with ball bearings opposite each other (and the rubber moving in between) , no proper water seal was obtained even though the moving force was much smaller.

A more satisfactory solution was found by inserting a hollow, air-inflated rubber cylinder (Seal Well, Western Brass Works) within the tubing. By regulating the air pressure within the cylinder, a good waterseal could be obtained while the cylinder moved up and down the tubing by applying a force of approximately 35 pounds (figure 4) . As two cylinders are required, one on each side of the discharge outlet (figure 3) , the total force to be applied to move a discharge outlet through a zippered tubing would be approximately 70 pounds. The force required to open and close the zipper is negligible.

To possibly reduce this force, the coefficient of friction was determined for rubber sliding over (treated and untreated) rubber. The treatments given and the results obtained are shown in table 1. It is noted that rubber sliding over rubber sprayed with Teflon showed the least friction and the least variability in friction, whether the surfaces were dry or moistened. Silicon-sprayed rubber showed slightly higher friction than Teflon-sprayed rubber.

Both the Teflon- and the silicon-sprayed surfaces produced a flexible film, as was evidenced in tests on the inflatable cylinder. The formation of the film appeared to be unaffected, when the diameter of the cylinder was increased from 34 to 42 inches. Either of these sprays could therefore reduce the moving force of 70 pounds if the films could stand up to wear under field conditions.

It is of interest to note from table 1 that untreated rubber showed considerable variation in the coefficient of friction in the presence of water. In some cases moist surfaces showed more friction than dry surfaces. This appeared to be caused by vacuum pockets that develop between moist or wet, untreated rubber surfaces when they are sliding over each other. On sliding, these pockets need be eliminated against atmospheric pressure.

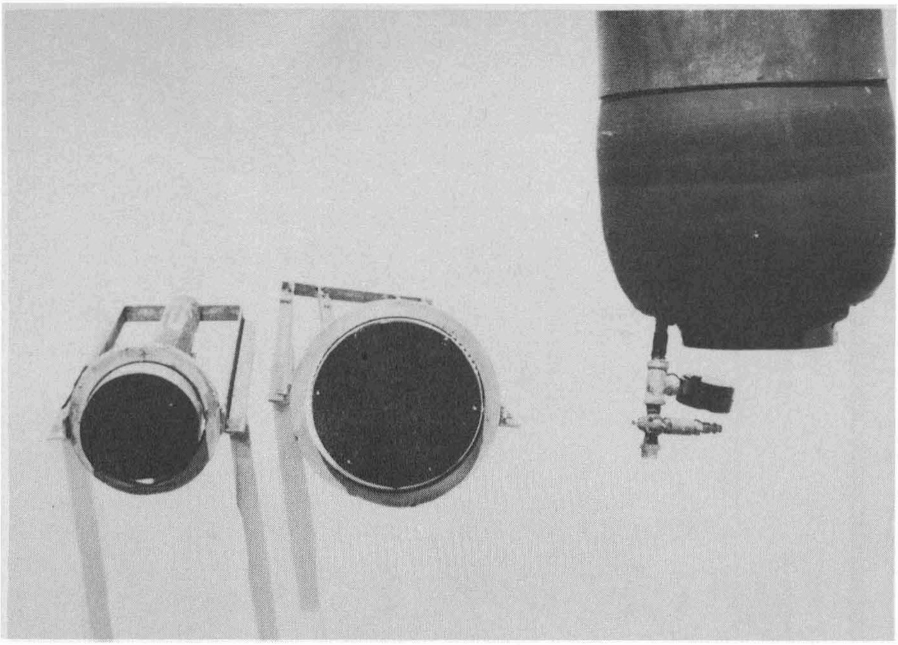

FIGURE 4. Model studies of waterseal for isolating discharge outlet from main body of zippered tubing.

At left: Exterior ring with ball bearings embedded at periphery of ring, opposite interior metal cylinder.

At center: Exterior and interior metal ring with ball bearings opposite each other.

At right: Hollow, inflatable cylinder used as seal.

While the inflated cylinder led to a satisfactory seal whenever pressure within the rubber tubing remained fixed, any increase in pressure within the tubing caused it to expand more than the cylinder did, so that the seal afforded by the inflated cylinder became ineffective. Therefore, either pressure within the tubing must be controlled, or material for the tubing wall must be selected that is flexible yet exhibits little variation in diameter with variation in pressure. This can be assured by the use of rubber reinforced with, for instance, nylon fibers.

TABLE 1. Coefficient of friction, μ, of butyl rubber sliding over butyl rubber

Treatment	Surface condition, Surface 1	Surface condition, Surface 2	Dry, moist, or wet	Individual Measurements of μ	Average of μ
1	molded	molded	dry	1.00; 0.90; 0.85	0.92
2	calendered	calendered	dry	0.80; 0.70; 0.70; 0.60; 0.60; 0.60	0.67
3	cellophane cure	cellophane cure	dry	0.64; 0.65; 0.35; 0.35; 0.47	0.49
4	cellophane cure	cellophane cure	wet	0.70; 0.70; 0.65; 0.72; 0.87	0.73
5	cellophane cure	cellophane cure	moist	3.99; 2.00; 0.75; 2.40; 1.25; 0.81; 0.75; 1.70; 1.20; 0.90; 0.75; 0.62; 0.85; 1.25; 2.00	1.42
6	cellophane cure	cellophane cure, treated with silicon spray	dry	0.50; 0.50; 0.50	0.50
7	cellophane cure	cellophane cure, treated with silicon spray	wet	0.40; 0.40; 0.40	0.40

(*Continued*)

TABLE 1. *(Continued)*

Treatment	Surface condition, Surface 1	Surface condition, Surface 2	Dry, moist, or wet	Individual Measurements of μ	Average of μ
8	molded	molded, treated with silicon spray	dry	0.60; 0.60; 0.60	0.60
9	molded	molded, treated with silicon spray	wet	0.30; 0.30; 0.30; 0.35	0.31
10	molded	molded, treated with silicon spray	moist	0.60; 0.80; 0.50; 0.47; 0.40; 0.40; 0.40	0.51
11	cellophane cure	Teflon	wet or dry	0.20; 0.25; 0.25; 0.30; 0.30; 0.30; 0.20; 0.35; 0.35; 0.22	0.27
12	molded	Teflon	wet or dry	0.20; 0.30; 0.25; 0.23	0.24

CONCLUSIONS

The conclusions drawn from the model study are:

(1) A discharge outlet can be moved within a zippered tubing with reasonable force.

(2) The size of the discharge outlet can be varied at will.

(3) A zippered tubing is probably leakproof at distances from the outlet, at field pressures.

(4) The Goodrich zipper tested is suitable, in a general way, but for the development of a field model requires smoothing of the inner surface.

(5) The discharge outlet can be made leakproof by inserting two, inflated hollow cylinders, one on each side of the outlet.

(6) Reinforced tubing, or equivalent material, must be selected with sufficient crosswise and lengthwise strength, so that the tubing shows negligible variation in diameter with variation in pressure within a given range and can withstand the force required to move the tubing past the discharge outlet.

REFERENCE

United States Navy. 1957. The steam catapult—its history and operation. NAVAER 00-80 T-69.