The Design Process for the IDE Low Cost Drip Irrigation System

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The First Idea for a Low Cost Drip System

I got interested in drip irrigation purely by accident, and I knew absolutely nothing about it at the time. We had run cargo tests with a five-ton jet barge from Idaho on a section of the Gandaki River in Nepal, and on the way back to Katmandu we passed through the hill town of Tanzen. S K Upadhya, the Managing Director of the Agriculture Development Bank of Nepal had been very enthusiastic about the results of introducing Bank supported small sprinkler systems in hill villages. These Rainbird type sprinklers were pressured by a 10,000-liter tanks located in small streams 20 meters in vertical height above the field. We stopped by the bank office in Tanzen to learn how much these hill village sprinklers

The bucket kit for low cost drip irrigation in the test laboratory of IDE India near New Delhi. A simple product with a long trial and error phase to make it suited to the needs of poor horticulturists.

cost, and ended up taking a half-day walk to three hill villages to see how they worked.

The 6 or 7 farmers we talked to were very happy with the systems and the high value horticultural crops they produced, but they cost too much to be affordable without a major government subsidy. Each sprinkler system cost about thousand dollars and served two farms each with one third to one half an acre of irrigated horticultural crops. I was curious about why these small sprinkler systems were so expensive. It turned out that the biggest single contributor to cost was the $300 investment in a 10,000-liter tank made of stone and cement. Then, to get 15 or 20 meters of head, the tank had to be a relatively long distance from the field, which required another significant investment in pipe to carry the water from the tank to the field. How could we design a system that would be much more affordable? I thought the most direct solution was to design a system that could operate under much lower pressure.

Why not just let the water dribble out of small holes in the pipe, instead of using a sprinkler? Would this allow the use of a much smaller tank that was much closer to the field, and just 2 or 3 meters above it? This would not only dramatically reduce the cost of the tank, but also decrease the investment in pipe connecting the tank and the field. We thought it might be possible to build a system like this for about $30 to irrigate a third to a half an acre.

We talked to Dan Spare, an irrigation engineer who had worked on Rower Pumps in Bangladesh and was now working on a small canal irrigation project on the Gandaki River in Nepal. He told us that a pipe with holes in it was a form of drip irrigation, and confirmed that such a system could indeed operate on 2 or 3 meters of head. I had noticed that just about every house in typical hill villages in Nepal had stuck a little piece of cheap black pipe in a stream above the house, and used the water it carried as wash water. I learned that the black pipe was called High Density Polyethylene (HDP), and it was cheap and readily available in most places in Nepal. If most remote villages in Nepal were already using this cheap HDP plastic pipe, why not use the same black pipe for the lines with holes in the new system?

When we got back to Katmandu, I wrote up a two-page concept paper with a simple drawing, proposing that we build a thirty-dollar irrigation system using HDP pipe, with the following components:

1. A used fifty-five gallon drum sunk in a stream 2 or 3 meters above the field
2. A simple filter using cloth or similar materials
3. A length of ¾ inch black HDP pipe running from the drum to the field
4. A T fitting at the field end of the pipe, to which three lengths of half inch HDP pipe would be attached, each of which would let water dribble out of holes to a row of plants
5. The holes in the pipe would be made with a hammer and a nail
6. The T junction with three pipes would be shifted by the farmer from one set of rows to another to irrigate the field

Surprisingly, this simple two-page report with a drawing, written without any knowledge of drip irrigation, contained all the key elements of IDE's current low cost drip irrigation systems. I would have been amazed to be told in 1992, that it would take 5 years of design work and adaptation by a team of IDE staff members in Nepal and India, before this simple initial idea could be transformed into a low cost system that worked.

Building the First Test Low Cost Drip Systems
We quickly learned that while it was easy to outline a plan for a simple appearing low cost drip system on paper, it was much more difficult to build a system that worked in the field.

1. **Making Uniform Holes in the Pipe** The first problem we ran into was that it was impossible to make holes in Nepal black HDP pipe with a hammer and a nail. Not only that, but it was critical for all the holes to be uniform so all the plants would get the same amount of water. It took a year or more for Bob Nanes, an irrigation engineer who was the IDE Nepal country director, and Deepak Adhikari, a creative Nepali engineer who worked with Bob, to solve this problem. They used a heated needle placed inside a soldering iron attached to a crank handle to punch uniform holes in the plastic pipe.

2. **Keeping the Water from Squirting Sideways.** Now we had relatively uniform holes in the pipe, but Bob and Deepak found that under 2 or 3 meters of pressure, water squirted out of the holes for 2 or three feet, ending up away from the plants. One day Bob's wife Maya was looking at a hair curler, and came up with the solution- take a two or three inch length of plastic pipe, slit it horizontally, and snap it over the hole as a baffle. This made the water fall beside the pipe to the row of plants.

3. **Finding a Low Cost Pressure Tank.** Bob and Deepak found that it was cheaper to use a simple 20 liter or 40 liter plastic tub from the local market, and hang it on a post or a tree 2 or 3 meters above the field, than it was to use a fifty five gallon drum

4. **The Problem of Plugging.** The IDE Nepal team learned from farmers who agreed to try out these first systems that plugging of the holes by dirt was the biggest practical problem. Conventional drip systems attack this problem by putting a major investment in filtration. To keep the cost down, Bob and Deepak opted instead for a simple filter, and made it easy for farmers to clear plugged holes. They made the holes in the pipe the same diameter as an ordinary safety pin, which farmers used to clear plugged holes. This worked very well.

5. **A Practical Low Cost Filter** Deepak and Bob used a simple flour sifter available in the local market, with pieces of nylon shopping bag and cloth inserted as filters that could be washed out every day.

6. Testing a Proof-of-Concept Prototype
After the year or so of time it took to develop a working low cost drip system using holes as emitters, Bob set up a test stand to measure the hole-to-hole uniformity of flow in the system. This is an important standard measure of drip system quality, and came out at about 85%, compared with the lab-tested uniformity of conventional drip systems of 95%.[1] But the cost of the IDE system was one third of that of conventional systems and

[1] Polak, Nanes, and Adhikari. A Low Cost Drip System for Small Farmers in Developing Countries. Journal of Water Resources, 1997

we learned that small hill farmers in Nepal did not consider a difference of 10% in uniformity very important.

Adapting the Technology Through Small Farmer Experience and Feedback
The next step was to get 10 small hill farmers to try the low cost drip systems on their vegetable crops, and tell us about their experience. Most of these 10 hill farmers were growing vegetables for sale in Katmandu, and they either had access to canal water or had been carrying water by bucket to irrigate their crops. The farmers were very positive about their experience with the small drip systems, and surprised us by saying that they required much less labor than surface flooding. They also said that the drip systems had lessened soil compaction, and improved crop yield. But they also had problems.

1. **Problems with Baffles-** the pieces of slit pipe that were snapped over each hole to keep the water from squirting sideways would often slide away from the hole during shifting of the lines. Deepak solved this problem by designing a baffle that gripped the pipe that could be extruded cheaply by local small shops.

2. **Poor Fittings** The fittings for attaching pipes to each other that were available in the local market worked poorly and often leaked. Deepak solved this problem by designing push-fit pressure fittings that made it easy for farmers to customize their systems, and talking a local entrepreneur into fabricating these push-fit joints cheaply in his small hand powered plastics injection molding workshop.

3. **Too Much Shifting.** Most farmers did not want to shift drip lines ten times, so Deepak and Bob modified the system to a one-shift or two-shift system

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4. **Disputes Over Water.** To our surprise, we learned that providing access to efficient water use through drip could precipitate disputes over water! One small farmer irrigated his vegetable plot by connecting his low cost drip system to a miniscule stream that was regarded as too small to use for irrigation. After seeing the valuable vegetable crop produced by the system, the farmer's neighbor cut his drip line and said that the water in the stream belonged to him. We made it a regular practice to involve the local village governance structure from the start of making drip irrigation available to village farmers.

After adapting the drip system technology and its dissemination to incorporate the experience of small farmers who had been using it, we were ready to begin the dissemination of the technology in India and Nepal.

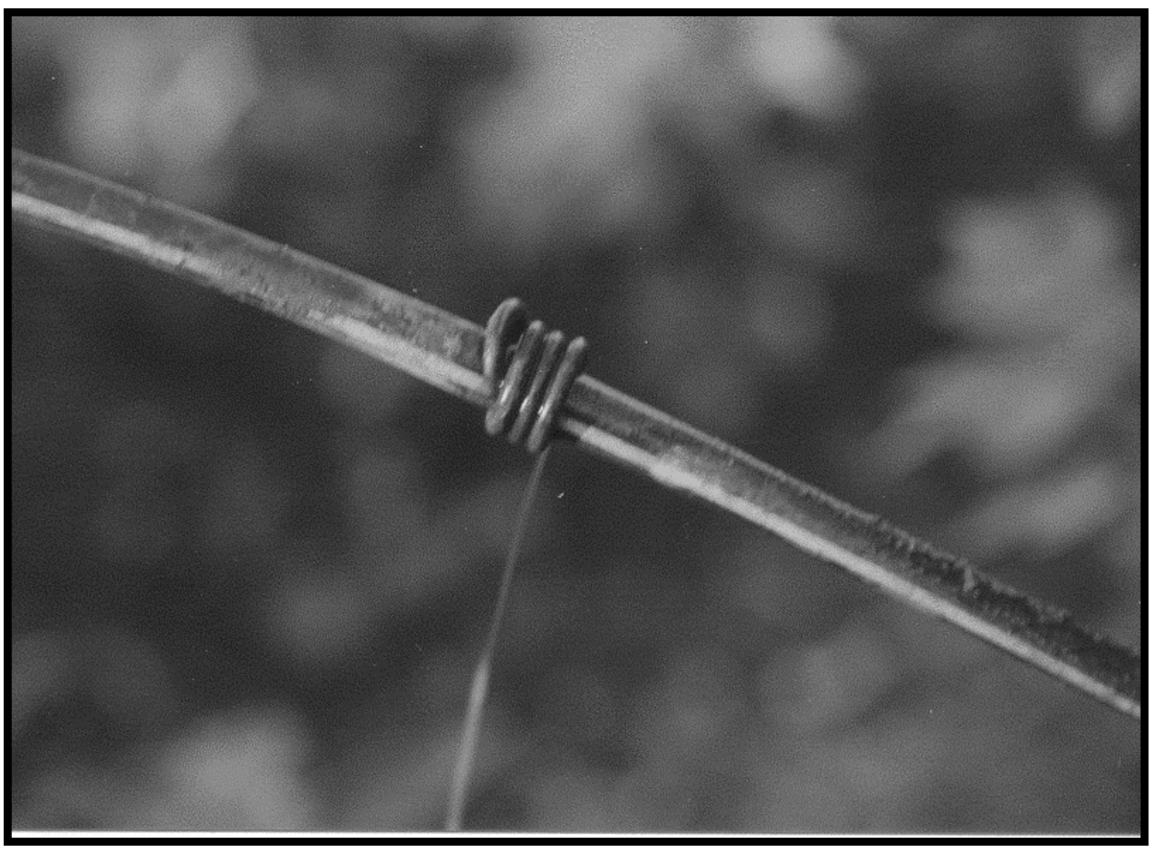
Introducing Affordable Small Plot Drip Irrigation to India
At this point, we discussed with Urs Heierli of SDC India the possibility of testing low cost drip irrigation technology developed in Nepal on an experimental mulberry farm for silkworm production in Andhra Pradesh in southern India. From the field tests that followed, we learned the following.

1. **Problems in Shifting.** Mulberry plants grow into 12 foot tall bushes or trees that are even bigger, and it is difficult to lift drip lines over mature mulberry plants to shift the lines. Many mulberry farmers are short on labor, and prefer non-shifting systems.

2. **More Problems in Producing Uniform Holes.** We expected to use the same heated punch method we developed in Nepal to make uniform holes in plastic pipe in India, but this proved impossible. The plastic lines used for drip irrigation in India are made from Linear Low Density Polyethylene (LLDP), and this is a much more elastic material than the more rigid High Density Polyethylene (HDP) black pipe of Nepal, and it stretches when a heated punch is applied to it, resulting in irregular holes.

Further Evolution of Low Cost Small Plot Drip Technology

After months of frustration, Bob Nanes from Nepal and irrigation engineers working for IDE India decided to try the concept of manufactured holes by inserting manufactured uniform diameter microtubes into holes made by a hand punch. This system was found to work very well, and had been thoroughly tested early in the history of the development of modern drip irrigation technology. We used a microtube curled around the lateral line for shiftable drip systems, and found that by using straight microtubes extending to the right and left from each lateral line, we could produce a straight microtube drip system in which one lateral line could irrigate either two or four rows without shifting. This latter system proved especially attractive to mulberry and silkworm farmers. Lab tests of the India LLDP Microtube system revealed that it had a



The „curled“ micro-tube dripper: simple, low cost, if it clogs, one can simply blow it through.

uniformity of 85%-90%, which was slightly better than that of the Nepal punched hole HDP system.

Meanwhile, in Nepal, Deepak Adhikari discovered that it was possible to produce soft PVC pipe from ordinary PVC extruders, and that this soft Pipe was preferred by farmers over the more rigid black HDP pipe because it was lighter, easier to shift, and more attractive in appearance. We now had at least three different kinds of low cost drip irrigation technology, each about one-third the cost of conventional drip irrigation.

1. **Shiftable, soft PVC Nepal System**
2. **Shiftable India Curled Microtube System**
3. **Non- Shiftable India Straight Microtube System.**

Comparisons of Low Cost Drip, Conventional Drip and Conventional Surface Irrigation

IDE India now tested the crop yield and water use of side by side small plots irrigated by conventional drip, IDE low cost drip, and conventional flood irrigation methods, using cotton, mulberry, sugar cane, and vegetable crops. These tests revealed that drip irrigation cut water use in half and increased the yield by 30% or more, compared with conventional flood, and there was no discernable difference in results between low cost drip and conventional drip technology.

Drip Systems That Are Expandable Like a Lego Set

A common observation in both India and Nepal was that some farmers either had very little cash to invest, or wanted to start their experience with a cautious investment, but at the same time have the option to expand their drip system if they were successful. Over time, we developed a range of drip systems that varied in size from 20 square meters to 10 acres, and varied in cost from $5 to $300 dollars an acre. A critical feature of these systems was that a farmer could start at any point in the size/cost continuum, and expand his drip system with the profits it generated.

Chapin Bucket Kits. Dick Chapin, President of Chapin Watermatics and Stan Doerr have developed a kitchen garden kit that consists of an ordinary household bucket hung at shoulder height connected through a small filter to a drip tape distribution system which waters a kitchen garden. Bucket kits are assembled in New York and sold in countries like Kenya for $10-12. They are being distributed primarily through church organizations in Africa and other countries. We hired Stan Doerr and his wife Beth agreed to visit our programs in Nepal and India and install Chapin bucket kit demonstration plots. Our experience was that these systems worked well for kitchen gardens, but it was easier for farmers to clear plugged holes or microtubes in the IDE systems than to clear emitters in drip tape that had become plugged with dirt. Drip tape was also more fragile than standard drip tubing, but the biggest disadvantage of drip tape was that it was not easy to fabricate locally, and was expensive to import. We found that it was possible to assemble bucket kits or their equivalent out of off-the-shelf locally available components in Nepal and India, and market them profitably through the local private sector, for $5, including the bucket, which was less than half the price of imported bucket kits. Bucket kits or their equivalent have now become the standard entry point for IDE expandable low cost drip systems.

Initiating Rural Marketing Through the Private Sector

We now began to apply the same approaches to rural mass marketing we had learned from the Treadle Pump program in order to initiate marketing these systems to small farmers in India and Nepal through the local private sector. There was no drip irrigation private sector in Nepal, so we convinced a small pipe manufacturer to begin producing low cost drip irrigation kits. In India, there already was a significant market for conventional drip irrigation, with 50 Indian manufacturers of drip irrigation equipment. But the smallest drip system available in India was a one-acre system, and the cost of conventional drip systems was $750 an acre, three times the cost of an IDE drip system. We were unable to persuade any of the 50 existing drip companies in India to enter the low cost small plot drip market, so we set up two small assembly plants making drip kits from off- the-shelf pipe and fittings.

Does the Design of Affordable Small Plot Irrigation Systems Create a New Market That Serves Poor Customers?

Before Ford used assembly line techniques to bring the price of cars down to a price low enough to make them affordable to the working man, automobiles were toys for millionaires. Before Sony used transistors to make radios small enough to fit in a shirt pocket and cheap enough to be affordable to high school students, hi-fi systems took up half a room and only music connoisseurs could afford them. Before Jobs and Wosniak built the Apple computer in a garage, computers filled whole buildings and could only be afforded by large universities. Can cutting the cost and size of conventional drip irrigation have a comparable impact on the existing global market for water saving irrigation?

The mass marketing of Treadle Pumps in Bangladesh has created a new market for affordable small plot water lifting irrigation, which has increased the net income of small poor farmers by $130 million a year. In IDE's first two years experience marketing low cost small plot drip irrigation in India and Nepal, 10,000 systems have been purchased by small farmers, a much steeper exponential sales curve than that of the first two years of Treadle Pump sales. There are hundreds of millions of farmers in the world who cultivate less than five acres on half acre plots, who could benefit from affordable small plot drip irrigation. But like the market for fancy sit-down restaurants before the advent of Mac Donald's, the present world market for drip irrigation caters exclusively to the rich. Could the present relatively small global sales of conventional drip irrigation in the range of $400 million a year explode by producing low cost small plot systems that fit the needs of the majority of the world's farmers? Only time will tell.