

# Texas Agricultural Extension Service

## LEPA CONVERSION AND MANAGEMENT

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Center pivot irrigation is used widely in Texas, largely because of the low labor requirements, improved water distribution, and relatively low capital costs on a per irrigated acre basis. There are approximately 9,500 pivots in operation, irrigating 1.75 million acres. Center pivot technology has developed greatly since it was patented in 1952. Escalating energy costs in the 70s and 80s contributed to the development of more efficient pivot technology. In certain areas of Texas, concern for the decline in underground aquifers and the long-term availability of water for irrigation has continued to foster the development and adoption of water conserving nozzles and pivot systems.

The LEPA concept grew out of efforts by agricultural engineers at Texas A&M University to develop a system that would reduce energy requirements of mechanical-move systems, while maximizing the use of both rainfall and applied irrigation water. Since the concept was first introduced in 1981, LEPA has been transformed into various commercial products that are now installed on more than 400 pivots in the state.

### WHAT IS LEPA?

LEPA is a highly efficient method of delivering water to crops from center pivot and linear move irrigation machines (Table 1). LEPA, which stands for Low Energy Precision Application, reduces water losses from wind drift and evaporation, improves yields and lowers energy costs for pumping. In many situations, these benefits warrant the conversion of existing equipment to LEPA. The extra cost of LEPA on a new center pivot is even more justified and should be carefully considered by prospective buyers.

LEPA discharges water through accurately designed and often pressure-regulated nozzles located from 8 to 18 inches above the furrow. This low discharge point greatly reduces spray and drift losses caused by wind, low relative

humidity and high temperature. Water losses are only 2 to 3 percent, compared to at least 20 to 25 percent from typical impact sprinklers and low pressure drop nozzles. For a center pivot operating at 800 gpm (gallons per minute), this difference means that from 160 to 200 gpm more water will reach the ground and crop.

LEPA's lower operating pressure normally will significantly reduce pumping costs. Twelve to 15 psi pivot pressure at ground level can be used for many quarter-mile systems on flat land. Half-mile center pivots that carry 2,000 to 3,000 gpm can be designed for 20 to 30 psi pivot pressure. Fuel consumption and costs have been found to average 15 to 20 percent less than for a center pivot equipped with low pressure spray heads, which is often 50 to 75 cents per hour less for quarter-mile units.

**Table 1. LEPA systems advantages and disadvantages compared to conventionally equipped center pivot systems.**

#### Advantages

1. High irrigation application efficiency (95-98 percent)
  - low wind drift losses
  - at least 20 percent more water will reach ground/crop
2. High uniformity
  - potential elimination of dry and wet areas
  - ideal system for chemigation
3. Reduced wetting of foliage
  - lower evaporation losses
  - potential reduction in certain disease problems
4. Potential reduction in energy costs for pumping due to
  - high irrigation application efficiency
  - low operating pressures
5. Three modes of operation allows the placement of water/chemicals exactly where needed.
6. Pivot tower wheel tracks remain dry when planting in a circle.

#### Disadvantages

1. Higher material and installation costs.
2. Wetter soil conditions and runoff may occur without proper management; furrow diking and planting in a circle are recommended.
3. Pressure regulators are generally required for proper nozzle flow.

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## DEVELOPMENT OF LEPA

LEPA technology developed from efforts to find methods of reducing water and energy use in irrigated agriculture. One aspect involved the elimination of the high spray evaporation losses common in Texas. For instance, Clark and Finley (1975) found that at a wind speed of 15 miles per hour (which is the annual average for the Texas High Plains) evaporative losses were 17 percent, and at speeds of 20 miles per hour losses were over 30 percent. In the Southern High Plains, losses on a linear-move sprinkler system have been measured as high as 94 percent when wind speed averaged 22 miles per hour with gusts of 34 miles per hour (Lyle and Bordovsky, 1981b). Another aspect involved designing a system to be used in conjunction with micro-basin land preparation or furrow diking, which prevents runoff and maximizes the use of rainfall and applied irrigation water. A double-ended sock (Fig. 1) was developed to accomplish both goals. No wind losses result since water is discharged directly into the furrow. Also, the open ends help preserve the dikes. However, this method can be used only for irrigation.

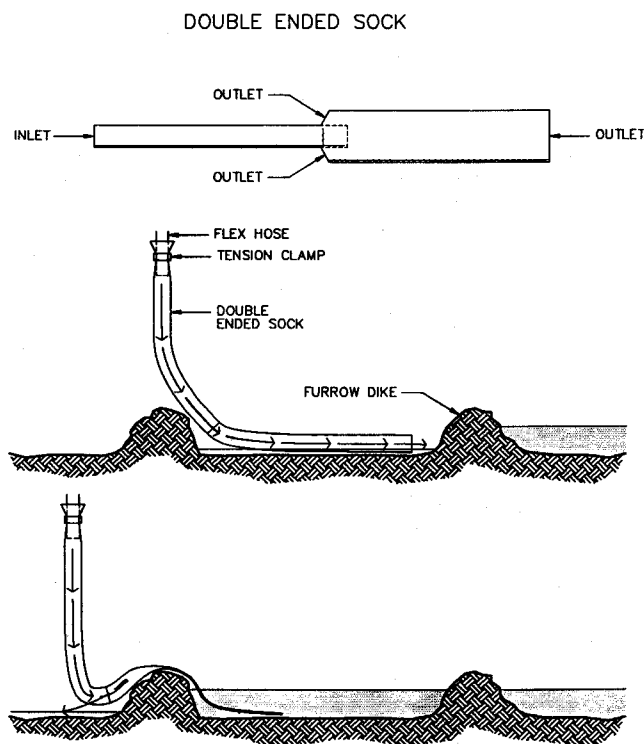


Figure 1. Low pressure, double-ended sock designed to be used in conjunction with furrow dikes. The sock prevents wind losses and helps preserve the dikes but can only be used for irrigation.

Lyle and Bordovsky (1981) of the Texas Agricultural Experiment Station in Lubbock conducted the first experimental work on LEPA using a linear-move system. In order

to reduce erosion of the furrow dikes, the researchers developed prototype orifice controlled nozzles which operated in the 1 to 5 psi (pounds per square inch) range and discharged water at low velocities in a bubble pattern. The orifices were attached to drops and located at a height of 2 to 4 inches above the furrows. Water losses with this system were found to be only 2 to 5 percent, compared to 25 to 30 percent for the conventional sprinkler system (Lyle and Bordovsky, 1983). On the experimental unit, a LEPA head was located in each furrow and furrow diking was used to increase surface storage to retain rainfall and applied irrigation water without runoff.

In 1983, Leon New of the Texas Agricultural Extension Service (TAEX) began working with LEPA with the goal of exposing growers to the experimental concept, developing a commercialized LEPA system which would be economical and suitable for use on both existing and new center pivots, and determining the design and management restraints of the concept. The most challenging aspects of this effort were developing and testing a commercial LEPA nozzle and head, reducing the costs of materials for LEPA and determining operation and management practices to make the most effective use of the developing technology in production agriculture.

Having drops in every furrow would have made LEPA too costly for most applications. Thus, a number of field trials were conducted during the 1983 and 1984 growing seasons on the Texas High Plains to determine whether LEPA heads could be placed in alternate furrows of crops planted in straight rows and in a circle. In these trials, individual spans on existing center pivot systems were converted to LEPA. One span or a portion of a span had LEPA drops in every furrow and one had LEPA drops in alternate furrows. All spans received appropriate inputs and the crops were harvested individually under each span. Yield data were obtained and are given in Table 2. These results demonstrated that LEPA heads could be placed in every other furrow without any yield reduction.

Table 2. Yields under spans converted to LEPA with drops in every row and in alternate rows on the same center pivot for crops planted in a circle.

ID	CROP	YIELDS (lb/ac)		percent difference of alternate rows
		every row	alternate rows	
83C	corn	13,293	13,372	+ 0.6
84CA	corn	11,982	11,948	- 0.3
84CB	corn	11,859	11,758	- 0.8
83GS	grain sorghum	7,555	7,530	- 0.3
83SF	sugar beets	48,540	49,600	+ 2.1

In the development of commercial LEPA heads and nozzles, TAEX worked with growers, manufacturers and distributors to develop a product that could be used in three modes of operation as illustrated in Figure 2. In this manner, the same product could be used for pre-irrigation and germination, irrigation in the highly efficient bubble mode during most of the growing season, and for chemigation of both low and high profile crops. The pressure regulator, when used,

being conducted to improve designs, performance and convenience, and to increase application of the LEPA concept.

### COMMERCIAL LEPA SYSTEMS

Two commercial applications of LEPA currently on the market are illustrated in Figure 3. On one product (Fig. 3a), the three modes of operation are accomplished by changing the pad and hood positions. Veins are necessary in pressure regulators for pivots operating at high pressures (high pressures are not required nor used routinely) to reduce vibrations and turbulent flow which can cause damage. On another product (Fig. 3b), pads are interchanged for each mode of operation and the position of the hood is changed and held with a clamp.

LEPA heads are connected to drops which, in turn, are connected to the center pivot main pipeline by a gooseneck or furrow arm (Figure 4). Drops are usually located in every other furrow. However, this arrangement is adjusted near the towers to keep a drop out of the wheel tracks so that they will remain dry. On some vegetable crops, drops are used in every furrow.

### Pressure Regulators

The two multi-functional LEPA heads illustrated in Figure 3 usually are equipped with 6 psi pressure regulators. A pressure of 9 psi at the inlet of these regulators is required for them to operate properly. By placing a pressure

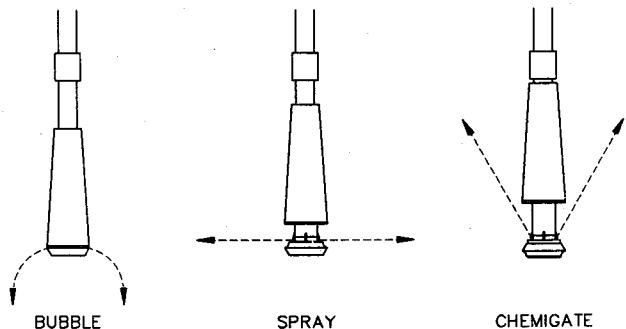


Figure 2. The three modes of operation for a modern LEPA sprinkler head: the bubble mode; the horizontal spray mode; and the chemigation (upward spray) mode.

was lowered and combined with the nozzle and other components to form the LEPA head. This lowered the required operating pressure by 4 to 5 psi and was a key development in lowering pumping costs for center pivot irrigation. This also necessitated the development and testing of higher pressure, flexible LEPA drop hose. Experimental work and field tests also showed that the optimum height for the LEPA head for growers was 8 to 18 inches above the ground. The development and design of LEPA heads continues to evolve. In cooperation with manufacturers, field evaluations are still

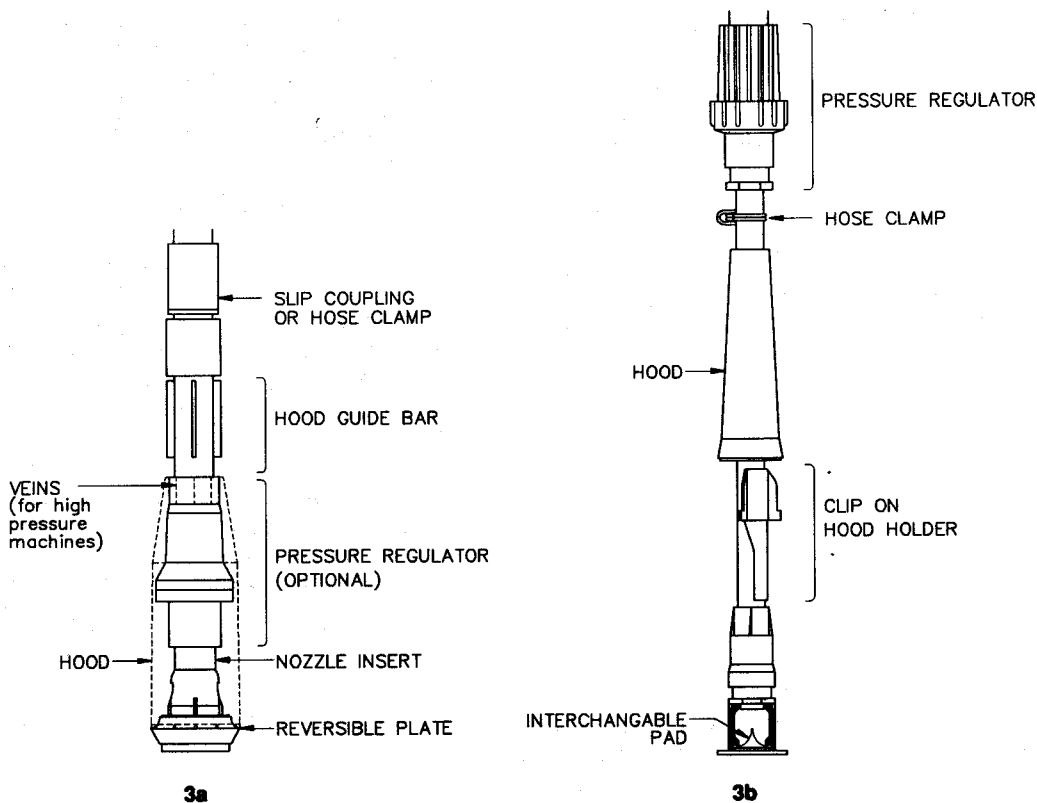


Figure 3. Two commercial, multi-functional LEPA heads currently available.

gauge in the lost drop (at the end of the pivot), pressure can be easily monitored to ensure proper, economical operation. One manufacturer also uses a 10 psi regulator for nozzle sizes up to 10.5 (64th) in order to provide a good upward spray pattern in the chemigation mode.

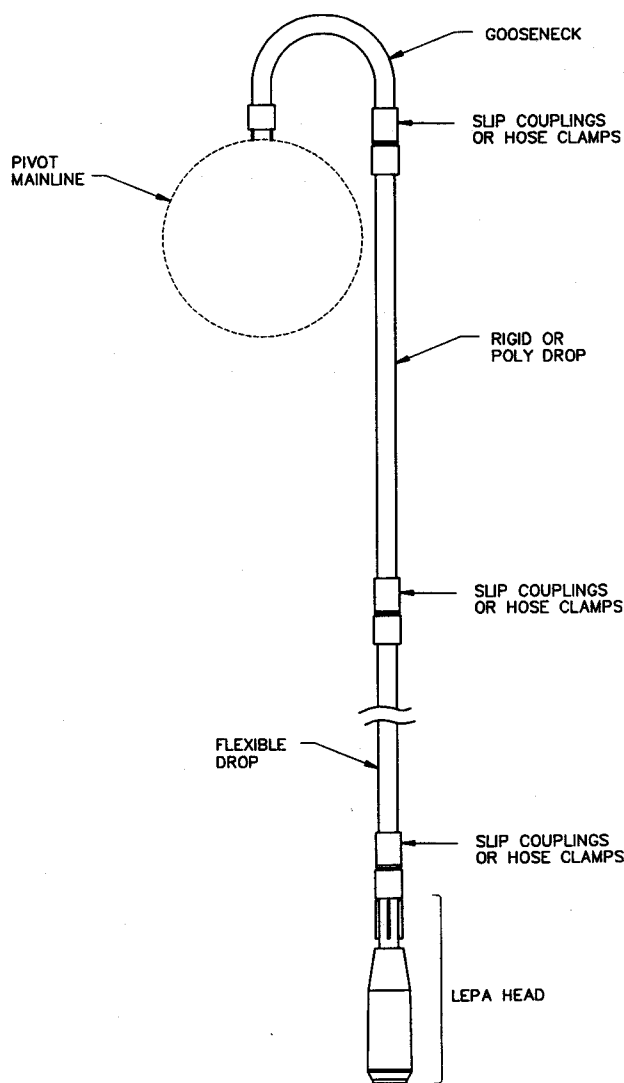


Figure 4. Typical drop arrangement for LEPA irrigation.

As with other sprinkler systems, pressure regulators are not necessarily needed for all sites. Pressure variations created by differences in land elevation can be controlled either by design pressure or with pressure regulators. Pressure at the LEPA nozzle should not vary more than 20 percent from

the design pressure. Generally, systems can be designed without regulators when the maximum elevation change is 5 feet or less from the pad to the end of the pivot (Table 3) without significantly increasing operation pressure and pumping costs. Where elevation changes are greater than 5 feet, the increased cost of regulators often can be recovered due to lower design pressures and the resulting lower pumping costs.

Table 3. Percent variation in system operating pressure created by changes in land elevation. Maintain less than 20 percent variation.

Elevation change Ft	psi	System design pressure (psi)				
		6.0	10.0	20.0	30.0	40.0
2.3	1	16.5	10.0	5.0	3.3	2.5
4.6	2	33.0	20.0	10.0	6.6	5.0
6.9	3	50.0	30.0	15.0	10.0	7.5
9.2	4		40.0	20.0	13.3	10.0
11.5	5		50.0	25.0	16.6	12.5
13.9	6			30.0	20.0	15.0
16.2	7				23.3	17.5
18.5	8				26.6	20.0

Of special concern are locations where flow rate or pressure varies significantly during the growing season because of increases in pumping lift such as those caused by seasonal variations in water tables. In such cases, the design flow rate (or system capacity) and the use of pressure regulators should be evaluated carefully. If operating pressure drops below 9 psi and regulators are used, poor water application and uniformity will result. In contrast, if the design operating pressure is high, pumping costs will be unnecessarily high. The pumping capacity of the well should be measured under anticipated system pressure to improve LEPA nozzling accuracy.

### YIELD COMPARISONS

A number of the field trials have been conducted to obtain yield comparisons between LEPA and conventionally equipped center pivots using partially-converted systems. Typical partial conversions used in these comparisons are shown in Figure 5. Usually the next to last full span is converted to LEPA. Yield from the next interior unconverted span is obtained for comparison and is given in Table 4. Yields are consistently greater from the LEPA span than from the unconverted span since more irrigation water reaches the soil and crop.

Table 4. Yields under LEPA with and without furrow diking.

ID	CROP	YIELD (lb/ac)		INCREASE WITH DIKES	
		diked	undiked	(lb/ac)	\$/ac <sup>1</sup>
84SF1	corn	10,580	10,170	410	22
89CT	peanuts	5,357	4,821	536	168
84SF	sugar beets <sup>2</sup>	8,260	7,189	1,080	178

<sup>1</sup> gross value of price received

<sup>2</sup> yields expressed in pounds of sugar produced per acre

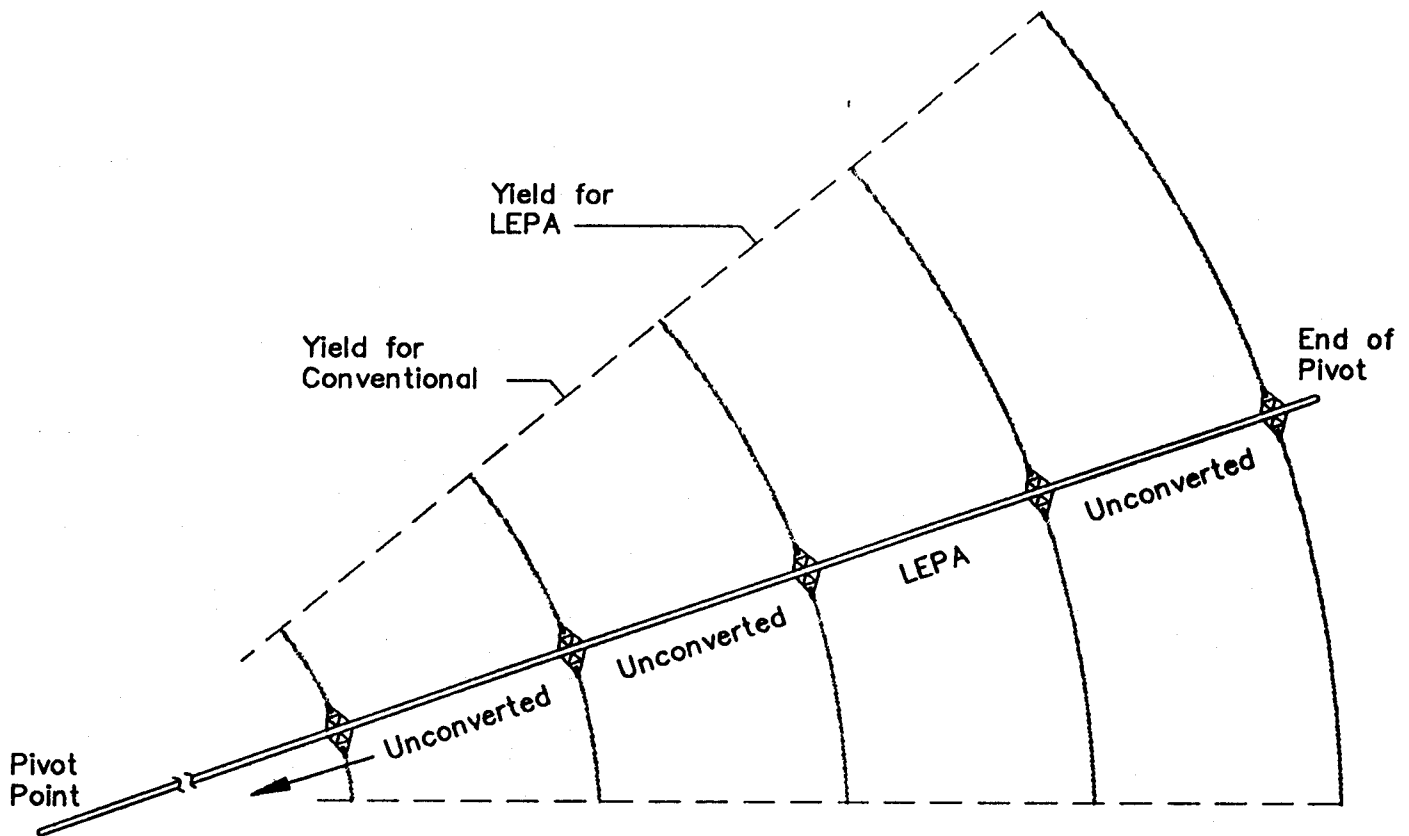


Figure 5. Arrangement used in field trials to compare LEPA to conventional sprinklers on partially converted systems.

## CONVERSION TO LEPA

Water outlets on existing center pivot mainlines are typically spaced 8 1/2 to 10 feet. Since LEPA drops are placed between every other crop row, additional plumbing is needed. For example, for row spacings of 30 inches, drops are needed every 60 inches (5 feet). Likewise, for 36-inch row spacings, drops are spaced each 72 inches (6 feet). Two methods can be used to install extra drops: 1) using the existing outlets and tees, hose and clamps; or 2) adding additional outlets.

### Existing Outlets

Figure 6 illustrates specially designed clamps attached to the center pivot mainline. Clamps are sized exactly for individual mainline diameters and are located to position LEPA heads in every other furrow. A rigid plastic drop is inserted through u-bolts in the clamp. Water is supplied from the existing mainline outlets to the drops with flexible 1/2-inch polyethylene drip tubing. Tees are installed at the outlets as needed. Flexible plastic hose is used to connect the drop to the LEPA head.

Total material costs for conversions varies depending on the supplier and location, but is often about \$22 per drop. Cost to convert quarter-mile center pivots for 40-inch crop rows is approximately \$4,500, and about \$5,500 for 30-inch rows. Conversion of a quarter-mile pivot can usually be completed in 100 to 120 man-hours. Installation time can be reduced by providing a platform underneath the pivot mainline, such as planks placed across the truss rods or the side boards of a truck.

### Additional Outlets

New mainline outlets can be quickly installed using a *swedge coupler* made of metal alloy. An appropriate size hole is drilled into the pivot mainline at the correct spacing. The swedge coupler is then inserted into the hole. The manufacturer recommends that a small amount of sealant be used with the coupler to ensure a leak-proof connection. A standard hydraulic press (body hydraulic punch equipped with a pull-type cylinder) is attached to the coupler with a special fitting that screws into the coupler. The press is used to compress the coupler against the inside of the mainline pipe to make a water-tight seal. The swedge coupler compresses quite easily; care is needed to prevent over-compressing the coupler. Regular goosenecks or furrow arms are then screwed into the coupler. Conversion costs are about \$500 less per span due to the elimination of tees, plumbing, clamps and labor.

Conversion to LEPA also can be accomplished by welding threaded 3/4-inch female couplings to the existing main line. Since welding destroys the galvanized coating, welded couplings are most applicable for ungalvanized main lines. As with the swedge coupler, existing goosenecks and drops can be used with the welded couplings.

### New Pivots

To accommodate LEPA, most center pivot manufacturers offer outlets spaced either 60 or 80 inches apart on the mainline as an option. Either spacing fits conveniently into 160-foot span lengths. This length and spacing also makes farming in a circle easier. A regular gooseneck (or furrow

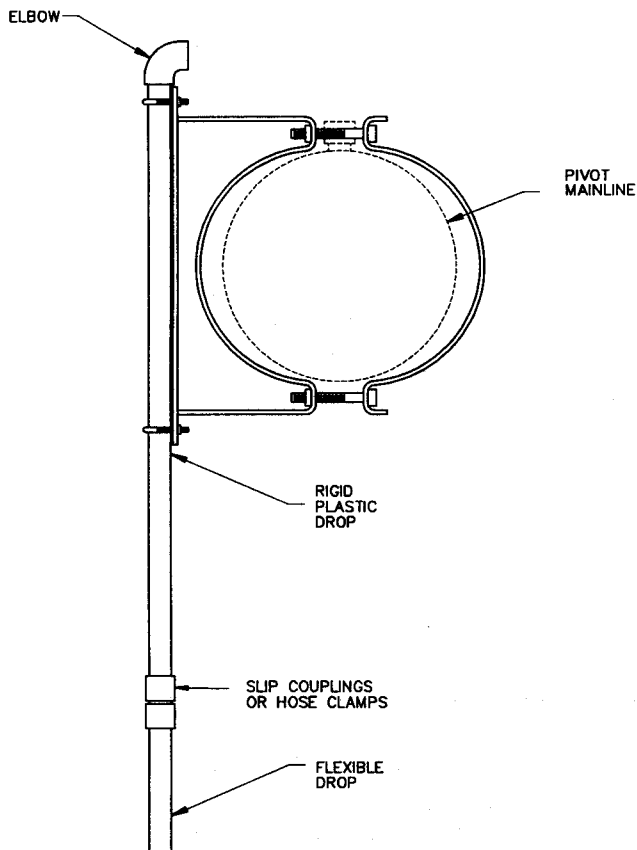


Figure 6. Mainline clamps for conversion of an existing pivot to LEPA by the addition of tees and plumbing.

arm) connects into the mainline outlet. LEPA heads are attached to a flexible hose that connects either to standard rigid drops or directly to the gooseneck. Both the 60- and 80-inch outlet spacing are suitable for 36-inch row spacing (or a drop every 72 inches) and most other row spacings by using appropriate length furrow arms. New quarter-mile center pivots can be equipped with LEPA components for \$3,000 to \$4,000 more than the cost of a new system equipped with conventional spray nozzles, depending on row spacing and the number of drops.

#### Other Conversion Tips

When water is pumped into a center pivot, it fills the mainline and drops. Weight of the water causes the pivot to "squat." For 160-foot spans, the pivot mainline will be lowered approximately 4 inches at the center of the span. Likewise, a 185-foot span will be about 6 inches lower at the center when filled with water. Length of the hose drops should be cut to account for this change so that all LEPA heads will be at the same height above the ground when the system is running.

Goosenecks and drops are installed alternately on each side of the mainline. This arrangement is recommended to

help equalize stresses on the pivot structure for high profile crops. Also, when crops are not planted in a circle, having drops on both sides of the mainline prevents all the water from being dumped into the same furrows when the system parallels crop rows.

## IRRIGATION WATER AND SYSTEM MANAGEMENT WITH LEPA

At least 20 percent more water will reach the ground with LEPA than with conventionally equipped center pivots. Operation and management practices must be adjusted to compensate for the additional water. Also, water is discharged directly into the furrow on a smaller soil area. Runoff will likely occur, especially on clay soils with slopes greater than one-half percent, unless furrow diking or other tillage is used to contain the water until it can move into the soil. Cultural practices such as furrow ripping, deep chiseling or other tillage and crop residue practices may be needed to improve the infiltration rate of the soil. Often the pivot must run at a greater travel speed to compensate for the additional water that reaches the ground. On most soils, individual applications of 2/3 to 1 inch can be made without runoff. Water can run up to 100 feet, but significant amounts should be prevented from leaving where it is needed by using appropriate tillage and management practices.

#### Planting in a Circle

Farming in the round is one of the best methods of reducing runoff and improving water distribution for both LEPA and conventionally equipped pivot systems. When crops are planted in a circle, the pivot never dumps all the water in a few furrows as it can when it parallels straight planted rows. Along with circular planting, ripping or other tillage practices are highly recommended with LEPA. Plan tillage operations so that LEPA heads always discharge water into the "soft" furrow and never into tractor wheel tracks.

Circle farming begins by marking the circular path the center pivot will follow. This is done by making a revolution without water. The tower tire tracks are then used as a guide. Next, calculate the number of rows that will fit into the span length of a pivot. For example, 48 40-inch rows (or 64 30-inch rows) will fit into a 160-foot-long span. Likewise, 74 30-inch rows will match up with 185-foot spans.

In some cases, row spacing will not match up exactly with the span length. For example, there are 71.6 30-inch rows in a 179-foot span. In order to produce an even number of rows (72), 12 inches less is needed (0.4 x 30-inch row). To lose 12 inches, set the tillage marker for the guide rows to proportionally lose 12 inches in the number of planter passes between and/or beyond towers. Put a furrow at the tower wheel tracks.

Some growers prefer to list towards the center from the tower track and make up any differences at the center by adjusting the drop position. Longer furrow arms may be required to achieve the necessary adjustment. Exactness is not essential since LEPA drop hoses are flexible. The hose and head can temporarily ride over the crop, then cross over

into another furrow if needed. Each attempt at planting in a circle will be more successful. Planting in a circle is essential to achieve the full benefits of insectigation of corn and similar high profile crops.

### Furrow Diking and Other Tillage Practices

Furrow diking is very effective at reducing runoff from LEPA irrigation, and was used in conjunction with the initial research. Furrow diking is a mechanical tillage operation that places mounds of soil at selected intervals across the furrow between beds to form small storage basins. Rainfall or irrigation water is trapped and stored in the basins so that it soaks into the soil rather than running off. Furrow diking has been found to reduce runoff and to increase yields in both dryland and irrigated crops (Jones and Clark, 1988; Lyle and Dixon, 1977). A complete discussion of furrow diking is given by Gerard (1987).

A number of field trials with furrow diking have been conducted under LEPA center pivots. In these trials, portions of the rows were diked with the remainder left open. Yields were taken separately from the rows with and without dikes. The results given in Table 5 show consistently higher yields with furrow diking. Similar results have been obtained by individual growers using ripping and other tillage practices, after the crop is up, in conjunction with LEPA. Where crops are planted in a circle, rip the furrow where water will be applied.

**Table 5. Yield comparisons under LEPA converted spans and conventionally equipped spans on the same pivot.**

ID	CROP	YIELD (lb/ac)		INCREASE WITH LEPA	
		LEPA	conventional	(lb/ac)	\$/ac <sup>1</sup>
86DM	corn (ensilage)	56,000	51,400	4,600	41
89LFA	corn (blue)	1,909	1,763	146	54
89TH	cotton	797	705	92	64
89 DK	cotton	562	483	79	73
89LFB	peas (purple hull)	1,267	1,055	262	42
85JHFA	peanuts (Pronto)	4,765	4,445	320	52
85JHFB	peanuts (McRan)	4,235	3,725	510	115
86JHF	peanuts (NC7)	4,310	3,210	1,100	203
89GTA	peanuts (Gk-7)	6,462	6,050	412	53
89GTB	peanuts (florunner)	6,534	5,978	556	120
89LF	peanuts (florunner)	3,689	3,267	422	177
83SF	sugar beets <sup>2</sup>	8,260	7,360	900	151

<sup>1</sup>gross value of price received  
<sup>2</sup>yields expressed in pounds of sugar produced per acre

The best furrow dikes are put in with moderate soil moisture. Do not attempt combined diking and ripping when soil is wet. The soil will not seal adequately underneath the dike and water will undermine the dike. In wet soils, use one or the other. Ripping or chiseling before planting is recommended where runoff is anticipated or has been a problem, and where it can be done in conjunction with land preparation. Rainfall can prevent timely tillage after the crop is up.

### Soil Moisture Monitoring

LEPA irrigations should be scheduled using soil moisture monitoring devices (i.e. tensiometers and gypsum blocks).

Soil moisture sensors can identify existing soil moisture, monitor moisture changes, locate the depth of water penetration and describe crop rooting. Gypsum blocks absorb and lose moisture from the surrounding soil; thus the moisture levels of the blocks is similar to that of the soil. Blocks are read with a resistance-type meter which indicates 10 (high) to 0 (low), although some newer digital meters read from 100 to 0. Tensiometer gauges indicate soil moisture by measuring soil moisture pressures in units of centibars, ranging from 0 (high) to 70 or 80 (low). Blocks can sense lower soil moisture and perform better than tensiometers in clay soils or in situations where the crops are irrigated infrequently. Readings may be taken at weekly intervals during most of the growing season. During peak water use periods, readings should be taken two or three times a week depending on rainfall and irrigations. Plotting readings on graph paper is the best method of tracking and interpreting sensor readings and determining when to irrigate. Table 6 shows soil moisture content for different sensor readings.

**Table 6. Guides of soil moisture content.**

Instrument	Excellent	Good	Fair	Low
Gypsum blocks <sup>1</sup>	9.5 - 10.00	7 - 8	5 - 6	3 - 4
Tensiometer <sup>2</sup>	20 or less	30 - 40	50 - 60	70 - 80

<sup>1</sup>Based on readings taken with Delmhorst type  
<sup>2</sup>Centibars of suction (soil water pressure)

A single block or tensiometer installed at a depth of 12 to 18 inches will measure moisture in the upper root zone; another installed at 36 inches will measure deep moisture. Generally, sensors are installed at three depths--12, 24 and 36 inches--and at a representative location in the field where the soil is uniform. Avoid slopes and low areas where water may stand. Select a location within the next to the last span but away from the wheel tracks. Locate sensors in the crop row so they do not interfere with tractor equipment.

Follow manufacturers' recommendations on preparing sensors. Gypsum blocks are usually soaked in clean water for 15 minutes and then allowed to dry two times before installation. Tensiometers are usually charged 36 to 48 hours before installation. Keep the porous tips submerged in a pail of water until installation. Install the sensors in a tight fit hole made with an auger or driver the same diameter as the gypsum block or porous tip. Pour a half cup of water in the hole before inserting the sensor. It is essential to have the sensing tip in firm contact with undisturbed soil to obtain accurate readings.

### Pressure Gauges and Monitoring

As discussed previously, LEPA systems installed with pressure regulators require at least 9 psi to operate properly. To ensure adequate pressure, install a pressure gauge in the last drop at the end of the pivot. Maintaining a pressure of 9 psi at this point will ensure proper operation. When the pressure gauge is installed directly on the end of the mainline, a reading of 4 psi is needed to ensure proper operation. Nine psi at the regulator is achieved by adding the 5 psi gain resulting from the 11- to 12-foot distance from the mainline

to the pressure regulator. A pressure gauge at the pivot point will give little indication whether proper pressure is being maintained. However, pressure gauges at the pivot point and at the well are effective for monitoring overall system performance. Operating pressures are low with LEPA which makes the system more sensitive to pressure changes.

## LEPA CHEMIGATION

Chemigation with center pivots is proving to be a cost-effective method of applying chemicals in a safe and timely manner. The high application efficiency and uniformity of the multi-functional LEPA heads make LEPA an ideal system for chemigation and a more valuable investment. Preliminary research has indicated that in some situations the amounts of chemicals applied can be reduced, resulting in lower costs and reduced environmental hazard.

### Safety Requirements

Federal regulation requires the use of specific chemigation injection and safety equipment (Table 7). These regulations were a part of EPA's Label Improvement Program (LIP) which became effective in April 1988. In addition to the regulations on equipment, the LIP requires that pesticide labels state whether the product may be applied through the irrigation system. If so, then application instructions are provided on the label. These requirements also aid the grower by providing for consistent, precise and continuous chemical injection, thus reducing the amounts (and costs) of chemicals applied.

**Table 7. Summary of chemigation equipment requirements.**

Components must include:	
1.	Irrigation pipeline <ol style="list-style-type: none"> <li>a. Check valve between well and injection points.*</li> <li>b. Vacuum relief valve between check valve and well.</li> <li>c. Low pressure cut off.</li> <li>d. Low pressure drain.*</li> </ol>
2.	Injection hose <ol style="list-style-type: none"> <li>a. Anti-back flow injection valve — 10 psi.</li> <li>b. Normally closed solenoid valve between injection pump and chemical tank.*</li> <li>c. A metering type injection pump.*</li> </ol>
3.	Power interlock <ol style="list-style-type: none"> <li>a. Interlock injection pump and water pump power.</li> <li>b. Interlock normally closed solenoid valve and injection pump power.</li> </ol>
* Alternative safety equipment may be substituted according to regulations approved by the EPA in March 1989. See TAEX Publication B-1652, "Chemigation Workbook."	

## Chemigation of Corn Pests with LEPA

Research at the Texas Agricultural Experiment Station in Lubbock (Lyle et al., 1989) has demonstrated that miticides can be effectively applied to the undersides of lower corn leaves (the area where mites feed) with LEPA in the upward chemigation mode (Fig. 1). LEPA nozzles designed for insectigation became commercially available in 1987 and were evaluated for control of corn pests under actual field conditions in 1987 and 1988. No difference in effective control was observed with start/stop electric-drive and continuous-move center pivots. More information is included in B-1652, "Chemigation Workbook," available from the Texas Agricultural Extension Service.

### Insecticide Formulations

The insecticide formulations best suited for chemigation are those which are soluble in oil but insoluble in water. However, since most insecticide formulations contain emulsifiers, the addition of a nonemulsified oil may be necessary to counter the effect of the emulsifiers. Nonemulsified vegetable and petroleum based oils have been used for chemigation with equal success. Typically, oils are mixed 1:1 with the insecticide. For vegetable oils such as cottonseed and soybean oil, use only "once refined" grade, as emulsifiers are sometimes added during later refinement.

Some insecticides such as pyrethroids and Lorsban® have low water solubility, so an oil carrier is not always needed. Other insecticides such as Azodrin® and methomyl are water soluble but not oil soluble, and perform poorly when chemigated since their high water solubility cannot be overcome by mixing with an oil. For additional recommendations see B-1652.

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