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EC754 Pump Irrigation

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Nebraska
COOPERATIVE EXTENSION WORK
IN AGRICULTURE AND HOME ECONOMICS
U. of W. Agr. College and U. S. Dept. of Agr. Cooperating
W. H. Brokaw, Director, Lincoln.

Extension
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754

PUMP IRRIGATION

by

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I. General Discussion.

1. Weather.

The dry weather of the last few years has created widespread interest in pump irrigation, even in our eastern counties. Inspection of weather charts show that since 1850, Nebraska has had three dry periods, one in the 60's, one in the 90's, and the present one. There is every reason to believe that a period of normal rainfall will follow this drouth and that interest in pump irrigation will wane in eastern counties.

2. Yields.

a. Eastern Nebraska.

In eastern Nebraska, much of the good bottom land soils would yield from 40 to 50 bushels per acre without irrigation in years of normal rainfall. Unless carefully managed, irrigation might not produce increases of more than 20 bushels in normal times. There might be many years when the outfit would not be used at all yet fixed charges go on just the same. The entire cost of irrigation would have to be charged to the increased yield on the years when pumping was done. Very good management would be necessary if pumping was made to pay except with inexpensive equipment such as could be used in pumping out of streams or very shallow wells.

b. Central and Western Nebraska.

The situation changes in central and western portions of the state where yields are relatively lower and the chance for a wider spread between irrigated and non-irrigated crops is better. The following table shows results of pump irrigation at North Platte Experimental Sub-station.

CORN - 1925-1934

Acres Irrigated	Acre Inches Applied	Cost per Acre	Averages		Increased Yield per Acre	Cost per Bushel Increase
			YIELD Irrigated	Dry Land		
32.4	13.74	10.15	55.82	18.54	37.27	29.55¢

POTATOES - 1925-1935

2.26	25.38	14.60	333.3	99.5	233.8	6.81¢
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3. Fertility.

Under dry land conditions, nitrogen often must be kept at low point in the soil to prevent over-stimulation and burning of plants. When irrigation water is available, a high nitrogen content is desirable if high yields are to be obtained. This suggests alfalfa, sweet clover, manures and plowing under of all available dry matter.

II. Hints to Pump Irrigators.

Observation has shown that many men are using pumps for irrigation under what would appear to be favorable conditions yet have made no appreciable advancement while others in the same community have made pumping pay a good profit. There seem to be certain points of similarity in the practices of those who prosper. Those who fail usually make about the same round of mistakes.

Following is listed some points of similarity between members belonging to each group.

Successful Pump Irrigator	Unsuccessful Pump Irrigator
1. Investigates to determine if soil is suitable for irrigation. Is it too drouthy? Is it underlain by hardpan?	1. Gives no consideration to soils until investment in equipment has been made and trouble develops.
2. Has preliminary levels run to determine pump location and to determine if fields can be watered. Estimates cost of land preparation, etc.	2. Guesses at well location and often misses.
3. Secures services of an experienced driller of irrigation wells, who has the equipment to do an efficient and workmanlike job.	3. Lets well contract to inexperienced man with poor equipment and ends up by paying him more money than a good well would cost.
4. Has test well dug with standard 6-inch casing and sand bucket and investigates underground conditions clear down to bed rock. Knows the whole underground picture when he has finished.	4. Starts drilling large sized well without test well and often encounters impossible underground conditions necessitating a change of location and wasted money.
5. Has a pumping test run on well to determine the drawdown at various yields. This permits purchase of most efficient pump for the conditions to be met.	5. Takes a chance on guessing at draw-down with good chance of always being wrong.
6. Purchases new and efficient equipment unless the total lift is very low.	6. Buys a second-hand pump which someone is anxious to unload because it is inefficient and requires a lot of power per acre foot of water pumped.

7. Finishes complete survey and map of farm; plans lateral and main ditch locations; plans row directions in all fields. This job is done mostly on paper and verified by field surveys.

8. Prepares land by dragging with irrigation leveling drag. May use Fresno scraper on high points. Continues preparation methods until water can be applied to crops with minimum of labor and expense.

9. Nitrogen content of soil raised by increased fertility. Sweet clover alfalfa manure used and all dry matter plowed under.

10. Uses water intelligently.

(a) Watches sub-soil moisture and starts irrigation before needed because time is required to cover fields with water.

(b) Uses water through a long season, waters in spring and fall as well as in summer. Has low per acre fixed charge because he irrigates large acreage with the plant.

(c) Has fields well prepared so distribution costs are low.

(d) Is very economical with water and does not let it run away in road ditches or does not soak up large areas of sub-soil below plant root zone by over irrigating.

11. Result: High yields and low cost per bushel of increase due to irrigation. Stabilized farm income and profit.

7. Guesses that the fields can be reached with ditches and that corn rows can be run in certain directions because the ground looks that way with the naked eye. Often discovers the mistakes too late to save a crop. May arrive at correct locations by cut and fit methods after years of trial and error.

8. Often does not discover that land needs leveling until irrigation is started. Always has high distribution cost per acre.

9. Continues with dry land methods and wonders why better yields are not obtained.

10. Usually is waiting for rain.

Starts two weeks too late when all signs of the moon and the almanac have failed to produce a shower. Often does not irrigate at all if there is any chance of getting part of a crop without it. Has high fixed cost because acreage covered is low. Wastes water by over irrigating in one place and missing other places entirely. Has high operating and per bushel cost due to inefficient pump, power plant and low increased yield per acre.

11. Result: Low yields, high cost per bushel increase due to irrigation. No profit from irrigation enterprise.

It is true that some men who have succeeded have not been entirely free from mistakes and, likewise, some who have failed have followed some good practices but, in general, the outline indicates the practices as followed by each.

III. Test Wells.

To determine the thickness and character of underlying strata, a test well is essential.

1. How Constructed

a. Hole bored to water table with a 6 or 8 inch auger.

b. A 4 or 6 inch standard pipe casing is inserted in hole.

- c. As material is removed from inside with a 3 or 4 inch sand bucket, the casing is forced downward.
- d. Test well should penetrate to bed rock.
- e. Samples should be taken of each different type of material encountered and careful measurements made of thickness of all formations.

2. Cost.

The cost varies from 35 to 50 cents per foot. Often cost for putting down more than one test well is less per foot. Some drillers make a discount on test well costs if land owner purchases an irrigation well and casing.

IV. Irrigation Wells.

1. Types of Casings.

a. Large diameter

Casings of wood or concrete of 6, 8, 10 foot or larger diameter are sometimes used where gravel sheets are thin and water table relatively close to surface.

b. Sheet steel galvanized casings of 12, 18, 24 or 30 inch diameters have become popular of late years. This casing is in 3 foot lengths and is made plain or perforated. Perforations are made by punching slots from inside $1\frac{1}{2}$ inches long and with openings $1/64$ to $1/4$ inches wide.

c. Concrete Casings.

For irrigation wells, concrete casings are made in diameter of from 24 to 30 inches. Various patented types are available.

d. Standard Pipe Casings.

Under some conditions, the standard wrought iron pipe casing of 6, 8, 10 or 12 inch diameter may be employed. They are put down much as described for the test well. When good gravel is penetrated, a screen is lowered inside the casing after which the casing is pulled up exposing the screen to the gravel.

2. Drilling Irrigation Wells.

a. Digging or Boring to Water Table.

A hole 6 to 8 inches larger in diameter than the casing is dug or bored to the water table. Casing is lowered into this hole and the sand bucket started. As material is removed from within, the casing is sunk by being weighted or with heavy levers. The space between the casing and the sides of the hole in the upper part of the well is sometimes partially filled with gravel. As the casing settles, this gravel is carried downward to replace sand which may be drawn into the casing by the churning action of the sand bucket. If well done, this process leaves a "gravel pack" around the perforated portions of the casing which is thought to increase the yield of the well.

b. Use of "blind" casing.

Some drillers first sink a large diameter "blind" casing to the depth of the proposed well. The casing proper is lowered inside the "blind" casing and the space between the two filled with gravel. The "blind" is then removed leaving the gravel surrounding the perforated portions of the casing proper.

3. Pumping Tests.

a. Yield of well.

No exact prediction can be made as to what the yield of a well will be until a preliminary pump test has been made. If the land owner is to get a pump well adapted to his particular use, he should have the information which this test will reveal.

b. Draw-down.

When an irrigation well is pumped, the water level in the well drops to a lower level. The amount of this drop is measured in feet and is known as the draw-down. For a given well, the draw-down ordinarily becomes greater and greater as the discharge is increased. The pump test should record the amount of draw-down for a series of discharge rates. From this information, an intelligent choice of a pump can be made.

c. Specific Capacity of Wells.

Other things being equal, a good well is one which will yield a large flow of water with a small amount of draw-down. In some cases, the water table in a well may be within 10 feet of the surface when no pumping is being done but, when yielding 1,000 gallons per minute, it may stand 30 feet below the surface. The water must then be lifted 30 feet with considerable increase in cost over another well where the draw-down is less. The specific capacity of a well is the number of gallons per minute yielded per foot of draw-down.

4. Well Development.

Certain processes have been devised for developing the flow of wells after they are finished. One method consists of lowering a plunger-like affair into water and plunging it up and down with the well rig. This draws sand in from surrounding gravels where it may be removed with sand bucket.

5. Costs of Wells.

Costs of wells vary a great deal depending on many factors. The figures given here are indicative of the prices charged by several drillers in Nebraska.

a. Large size casings and wells.

Wells of 6, 8, 10, 12 foot diameters may run as high as \$2.00 per foot in diameter per foot in depth.

b. Gravel treated concrete cased wells.

Wells of 24 to 30 inch diameter are commonly priced at \$10.00 per foot in depth including casing and gravel packing.

c. Sheet steel galvanized casings.

Casing Size Inches	Drilling Cost per Foot	GALVANIZED STEEL CASING COSTS PER FOOT					
		16-gauge		14-gauge		12-gauge	
		Plain	Perforated	Plain	Perforated	Plain	Perforated
12	\$2.50	\$.85	\$1.05	\$1.05	\$1.30	\$1.45	\$1.85
16	3.75	1.10	1.40	1.40	1.70	1.90	2.35
18	4.50	1.25	1.55	1.55	1.95	2.10	2.65
24	6.50	1.65	2.05	2.10	2.60	2.80	3.50
30	7.50	1.90	2.35	2.35	2.90	3.15	3.95

V. Pumps for Irrigation.

1. Types in Common Use.

a. Horizontal Centrifugal

The horizontal centrifugal pump is well adapted to use for low heads such as are encountered when pumping out of ponds, streams or shallow wells. The pump is built in all sizes and per unit capacity is cheaper than other types. Since it must be placed above the water level, its use is limited by the suction lift which should not exceed 15 to 20 feet.

For use in wells where the water table is near the surface, the pump may set on the ground surface or be placed in a pit, if the suction lift is too great. It may be belt driven or may be direct connected to electrical or gasoline motor. If operated at the correct speed for the total head, efficiency may be as high as 70 to 80%.

The following table gives approximate capacities of horizontal and vertical centrifugal pumps with given size of discharge.

Size Discharge	Delivery in Gallons per Minute	Efficiency in Per Cent
2 inch	200	40-60
3 "	300	65-75
4 "	500	65-75
5 "	700	65-75
6 "	1000	70-80
8 "	2000	70-80

The horizontal type of pump cannot be submerged and, therefore, must be primed before it will start. One method consists of putting a foot valve in the suction line. A valve may be placed in the discharge line and when closed, a suction pump may be used to draw water into the whirling impeller.

b. Vertical Centrifugal.

The vertical centrifugal pump is not essentially different from the horizontal in use limitations except that it may be submerged while the drive pulley is placed at a remote point. The pump is held in a steel or wooden frame which stands vertically in the well and supports the drive shaft to a point above the ground surface, where the belt pulley is placed. In some of the more recently developed types, the delivery pipe from the pump to the surface supports the drive shaft instead of a frame and the size is thus reduced to fit a well casing as small as 24 inches in diameter.

c. The Turbine.

The turbine is in reality a form of vertical centrifugal pump. Instead of one impeller and one case, there may be several impellers each on the same drive shaft and each running in a bowl or case which is so designed that the flow is directed from the discharge of one impeller to the intake of the one above.

By using an additional impeller or stage for each 15 to 20 feet of total head, the turbine may be used for a wide range of conditions. On the whole, pumps of this type are well designed and considerable attention has been given to the production of a dependable and efficient piece of machinery.

The turbine is adapted to heads of from 40 to 200 or more feet yet is small in diameter which permits its being inserted in casings of from 6 to 24 inch diameter. In design, the turbine consists of a cast iron pump head which carries the entire weight of the pump at the ground surface. The pump head supports the discharge pipe within which is the tube carrying the bearings and the drive shaft extending from the head down to the impeller. The pump bowls within which the impellers rotate are supported by the discharge pipe and may be set at any depth below the surface.

The pump may be driven with a flat or multiple V-belt pulley or may be had with a direct connected motor of several standard speeds. There is a tendency toward the use of the turbine pump for heads exceeding 40 or 50 feet, due to its higher efficiencies over a wide range of conditions.

d. Propeller Pump.

The so called "propeller" type pump has been developed for delivering large volumes of water through low heads. It is well adapted for pumping from streams, lakes and ponds or shallow wells. Essentially this pump consists of a long, vertical pipe containing a drive shaft along which helical shaped propellers are placed at intervals. When operated at correct speeds for given heads, this pump may develop good efficiency.

2. Power Required for Pump Operation

a. Pump Efficiency

The power required for pumping depends upon the amount of water to be delivered per minute, the height or total head through which it must be lifted and the efficiency of the pump. The more efficient the pump, the less power required, other things being equal. Centrifugal pumps must be properly operated to give high efficiencies and manufacturers recommendations as to speed, etc. should be carefully followed.

b. Power Requirements.

The following table gives the approximate horsepower required for lifting various quantities of water through various heads:

Gallons per Minute	LIFT IN FEET							
	10'	20'	30'	40'	50'	60'	80'	100'
	Horse Power Required							
200	1.0	2.0	3.0	4.1	5.1	6.1	8.1	10.1
300	1.5	3.0	4.6	6.1	7.6	9.1	12.2	15.2
500	2.5	5.0	7.6	10.2	12.7	15.2	20.3	25.3
600	3.0	6.1	9.1	12.2	15.2	18.2	24.3	30.4
700	3.5	7.1	10.7	14.2	17.8	21.3	28.4	35.5
1000	5.1	10.1	15.2	20.3	25.3	30.4	40.5	50.6
1200	6.1	12.2	18.3	24.3	30.4	36.5	48.7	60.8
1500	7.6	15.2	22.8	30.4	37.9	45.5	60.6	75.8

In above table, the pump efficiency is 50%

5. Pump Selection.

The intelligent selection of a pump requires that certain facts regarding the well be known which can be determined only by a pump test of the well. The well may be capable of yielding only 500 gallons per minute without excessive drawdown. There is little object in purchasing a large pump with a normal discharge of 1,000 gallons per minute which cannot be run at capacity and may operate at low efficiency.

4. Cost of Pumping Equipment.

Accurate figures on pumping equipment costs must, of course, be obtained for each individual job. The following is given to indicate relative costs of pumps of 1,000 gallon per minute capacity.

Horizontal Centrifugal	Vertical Centrifugal	Turbine
\$125.00 - \$175.00	\$325.00 - \$350.00	\$650.00 - \$850.00

VI. Power for Operation of Irrigation Pumps.

1. Choice of Power Plant.

The choice of a power plant for operation of an irrigation pump must be guided by many factors some of which are mentioned:

a. Power Required.

It is obvious that if the pumping job requires from 50 to 75 horsepower, ordinary tractors or discarded auto engines cannot be used. Such jobs would require large electric motors or perhaps Diesel engines.

b. Length of Irrigation Season.

The pump irrigator who uses an outfit for a long period each year and irrigates a considerable acreage of land might well afford a Diesel engine and a high efficiency turbine pump. The man who occasionally pumps from a stream on dry years only had best use the farm tractor and a common horizontal centrifugal pump, thus avoiding high fixed costs for depreciation and interest on investment.

2. Types of Power.

a. Farm Tractors

The farm tractor should receive consideration as a source of power for driving the irrigation pump in cases where it has sufficient power for the job and where irrigation is practiced through a short season, say, a month or six weeks. In eastern Nebraska, irrigation will not be practiced every year and often during a short season of extreme drouth, one or two waterings of corn will be the extent of the irrigation practiced on most farms. By using the tractor, which is already part of the farm equipment, high fixed costs can be partially eliminated.

b. Auto and Truck Engines

Engines from discarded autos and trucks are used to some extent as irrigation power plants. Many of these engines are badly worn in service and have little valve left when purchased by the irrigator. For pumping where power requirements are low and where irrigation is practiced during a short season, they have some value. With such equipment, operating costs are high as the amount of fuel and oil consumed per horsepower hour is large, in comparison to new equipment better suited to the job.

c. Diesel Engines.

The development of the high speed, small sized Diesel unit has been advantageous to the pump irrigator who operates an outfit 1500 or more hours per year. The Diesel engine develops approximately twice the number of horsepower hours per gallon of fuel as can be done by ordinary multi-cylinder gasoline engines. The fuel cost per gallon for Diesel fuel is about one-half the cost of gasoline or less.

The cost of a Diesel power unit runs from \$50.00 per horsepower up. An investment of \$2000.00 or more for a power plant of this type would be well warranted for an operator with a high power requirement and long operating season but certainly would not pay the occasional irrigator.

d. Electric Motors.

Electric motors for irrigation must in most cases be of the 3-phase type due to large horsepower required. Many of the rural lines now being built are of single phase circuit and only small sized motors (5 horsepower or less) can be successfully operated.

VII Costs of Pumping for Irrigation

1. Fixed Costs.

Certain fixed costs representing interest on investment and depreciation of equipment must be considered. These costs must be reckoned with whether the irrigation plant operates or not. The following examples might serve to illustrate fixed costs:

a. Plant No. 1

Used in eastern Nebraska for occasional pumping from stream.

Six inch centrifugal pump cost	\$175.00
Second hand automobile engine.....	100.00
Pipe and Accessories	100.00
TOTAL COST	\$375.00

Interest on \$375.00 @ 5%	\$18.75
Depreciation on machinery \$275.00 @ 8%	22.00
Depreciation on pipe \$100.00 @ 5%	5.00
TOTAL FIXED COST	\$45.75

Acres irrigated per year 40. Fixed Cost per Acre $\frac{45.75}{40.00} = \$1.14$ per A.

b. Plant No. 2

Used in central Nebraska for pumping from deep well.

100-foot well and casing	\$550.00
Turbine Pump	950.00
Diesel Engine	2150.00
	\$3650.00

Interest on \$3650.00 @ 5%	\$182.55
Depreciation on machinery \$3100 @ 8%	248.00
Depreciation on well and casing \$550 @ 4% ..	22.00
TOTAL FIXED COST	\$452.55

Acres irrigated - 100. Fixed Cost per A. = $\frac{452.55}{100} = \$4.52$ per A.

c. Lowering Fixed Costs per Acre.

It is at once evident that the fixed cost per acre can be reduced for any given plant by irrigating more acres per season. In eastern Nebraska, the fixed costs per acre may be high when an irrigation plant is used only on occasional dry years. This is especially true when the original investment per acre for irrigation equipment is high.

2. Operating Costs.

Operating costs, for any particular irrigation plant, will depend upon the amount of water pumped. Operating costs may vary greatly between individual pumping plants depending on overall plant efficiency, type of power plant used and cost of fuel or electricity.

a. Units of Measurement.

Acre Foot - The acre foot is the amount of water required to cover one acre one foot deep.

Acre Foot Foot - The acre foot foot is an acre foot of water pumped against one foot of head or lift.

It is customary to measure operating costs by acre foot foot units. For instance, if it is said that a certain plant has an operating cost for fuel of 8 cents per acre foot foot and the total lift is known to be 50 feet, then the operating cost for fuel is $50 \times 8\text{¢} = \$4.00$ per acre foot.

b. Examples of Operating Cost.

Plant No. 1

This plant is the same one mentioned under fixed costs. Used for pumping out of a stream, total head 30 feet, old 6" horizontal centrifugal pump, efficiency 40%, power plant is old automobile engine, gasoline cost 18¢ per gallon.

Operating cost for fuel is 9¢ per acre foot foot or $30 \times 9\text{¢} = \$2.70$ for each acre to which one foot of water is applied. To this must be added cost of applying water and attending the pumping plant.

Plant No. 2

This is the deep well outfit mentioned in paragraph on fixed cost. Used for deep well pumping, total head 60 feet, turbine pump with efficiency of 65%, power plant is Diesel engine, fuel cost 10¢ per gallon.

Operating cost for fuel is 2¢ per acre foot foot or $60 \times 2 = \$1.20$ for each acre to which one foot of water is applied. To this must also be added cost of applying water and attending plant.

c. Total Costs.

It is evident that for Plant No. 1, fixed costs are low and operating costs are high while the opposite is true for Plant No. 2.

Plant No. 1

Fixed Cost per Acre	\$1.14
Operating Cost per Acre ...	2.70
TOTAL COST	\$3.84

Plant No. 2

Fixed Cost per Acre	\$4.52
Operating Cost per Acre	1.20
TOTAL COST	\$5.72

In each case, it is assumed that one foot of water is applied to each acre and to above costs must be added cost of applying water and attending plant.

d. Cost Data from Surveys.

The following data is summarized from various surveys made of Platte valley pumping plants.

1. Cost of well and pump average \$750.00 to \$1,000.00
2. Operating costs for power vary from 2.9 to 30.2 cents per acre foot foot. An average of 6.7 to 9 cents per acre foot foot is thought to be representative.
3. Average operating cost for Platte valley wells including attendance of outfit would probably average 10 cents per acre foot per foot of lift.
4. Cost of applying water varies greatly between individual farms but averages \$3.50 per acre foot.
5. Acreage served by 6" pump is low averaging 55 acres.

VIII. Convenient Tables and Constants.

1. Rate of Applying Water.

ACRES IRRIGATED IN 10 HOURS PUMPING AT VARIOUS RATES OF FLOW

Rate of Flow Gallons per Minute	Depth Applied in Inches					
	1	2	3	4	5	6
	Acres Irrigated in 10 Hours Pumping					
100	2.2	1.1	.7	.5	.4	.36
150	3.3	1.6	1.1	.8	.7	.6
200	4.4	2.2	1.5	1.1	.9	.7
250	5.5	2.8	1.8	1.4	1.1	.9
300	6.6	3.9	2.2	1.6	1.3	1.1
400	8.8	4.4	2.9	2.2	1.8	1.5
500	11.0	5.5	3.7	2.8	2.2	1.8
600	13.2	6.6	4.4	3.3	2.6	2.2
700	15.5	7.7	5.2	3.9	3.1	2.6
800	17.7	8.8	5.9	4.4	3.5	2.9
1000	22.1	11.0	7.4	5.5	4.4	3.7
1200	26.5	13.3	8.8	6.6	5.3	4.4
1500	33.1	16.5	11.0	8.3	6.6	5.5

2. Friction Loss in Pipe.

Gallons per Minute Flow	Diameter of Pipe						
	4	5	6	8	10	12	14
	Lost Head in 100 Feet of Iron Pipe						
400	15.82	5.33	2.21	.56	--	--	--
450	19.75	6.65	2.74	.64	.21	--	--
500	24.08	8.12	3.26	.81	.28	.11	--
750		17.22	7.00	1.74	.59	.24	.11
1000			12.04	3.02	1.01	.41	.19
1250			18.20	4.45	1.51	.62	.29
1500				6.27	2.09	.85	.39
2000				10.71	3.50	1.43	.66

8. Horsepower and Electrical Data.

1 Horsepower = 746 watts
1 Kilowatt = 1000 watts = 1.3405 Horsepower

(Horsepower required) = $\frac{\text{Gals. per Minute} \times \text{Head in Feet}}{3960 \times \text{Efficiency of Pump}}$
(for pumping)

1 acre foot = 12 acre inches = 43,560 cubic feet.

1 cubic foot per second = 448.8 gallons per minute

1 cubic foot = 7.4805 gallons = 62.4 pounds

IX. Literature on Pump Irrigation.

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