BASIC INFORMATION ON IRRIGATION PUMPING COSTS

Irrigation pumping plants have been used in New Mexico since the early 1900's with the majority of pumping installations now located in the eastern part of the state.

As the cost of fuel, whether it be natural gas, diesel, or electricity increases, and/or the depth to water increases, the cost of pumping irrigation water becomes one of the most important factors to be considered in an irrigation system. Irrigation pumping costs currently account for about 50% of crop production costs, and, with the emphasis on conservation tillage systems which reduce the amount of tractor-related production costs, irrigation pumping costs will probably account for an even higher percentage of the total production costs in future crop production systems.

Irrigation Pumping Costs can be used as a catalyst for discussion with the landowner of numerous items:


2. Possible yearly energy savings if pumping plant is adjusted to higher efficiency level.

3. Value of possible energy savings to landowner by increasing level of irrigation water management, increasing the efficiency of the irrigation hardware system, or increasing the efficiency of the irrigation delivery system.

To provide the landowner with the best possible resource data on which to base alternative decisions, SCS personnel must be aware of the current pumping costs in their particular field office.

Since the SCS does not always have the facilities to gather pumping cost data and evaluate pumping plants on a state-wide basis, we rely heavily on data gathered by other agencies. New Mexico State University and Texas Tech University have long been prime sources of pumping cost data applicable to New Mexico.

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A word of caution must, however, be given before we can use any pumping cost figures. Many pumping cost figures reflect only fuel costs for irrigation pumping plants. Since the cost of pumping irrigation water includes not only fuel, but also interest, depreciation, taxes, insurance, and maintenance costs, the fuel cost alone does not reflect the total pumping cost figure.

The attached fuel costs reflect current tests conducted by New Mexico State University and should be used to supplement data collected by SCS field evaluations. Field office personnel should make every effort to keep these costs updated to reflect current fuel cost increases.

This chapter of the Irrigation Guide has been prepared to provide SCS personnel in New Mexico with the following information:

1. Basic Information on Irrigation Pumping Costs and Pumping Plants

2. Guidelines on Conducting Actual On-Farm Pumping Cost Evaluations

3. Actual Irrigation Pumping Costs for Selected Areas of New Mexico

4. Fuel Cost Comparisons Between Various Types of Pumping Plants

5. Actual Examples of How to Use Pumping Cost Data in Conservation Planning and Irrigation Water Management
DEFINITIONS AND ABBREVIATIONS USED IN PUMPING PLANT EVALUATIONS

Static Water Level - (SWL)
The level at which water stands in a well when no water is being pumped. Normally it is the measured distance from the water level in the well to the centerline of the pump discharge pipe.

Pumping Water Level or Pumping Depth - (PWL)
The level at which water stands in a well when the pump is running. Normally it is the measured distance from the water level in the well to the centerline of the pump discharge pipe.

Pump or Well Drawdown -
The difference between the static water level and the pumping water level or depth.

Total Dynamic Head - (TDH)
The total actual head that the pump is operating against.
TDH (feet) = (lift in feet) + (discharge head in feet) + (head loss in pump column in feet).
Discharge head (feet) = (2.31)(discharge pressure in psi).

Horsepower - (HP)
The amount of work or energy required to lift 33,000 pounds, a distance of one foot, in one minute.
One HP = 2547 BTU of heat energy.
Average energy values of fuel expressed as water-horsepower are as follows:

One gallon of LP gas = 35.96 HP
One gallon of regular gasoline = 48.76 HP
One gallon of diesel = 54.34 HP
1000 cubic feet (Mcf) natural gas = 392.77 HP
One kilowatt hour (Kw) electricity = 1.34 HP

British Thermal Unit - (BTU)
A measure of the heat energy required to raise the temperature of one cubic centimeter of water one degree centigrade. Average energy values of fuels expressed in BTU's are as follows:

One gallon of L.P. gas = 91,600 BTU
One gallon of regular gasoline = 124,200 BTU
One gallon of diesel = 138,400 BTU
1,000 cubic feet (Mcf) natural gas = 1,000,000 BTU
One kilowatt hour (Kw) = 3,413 BTU

Water Horsepower - (WHP)
The work output of a pumping plant in terms of horsepower. It is the useful or accomplished horsepower based on the amount of water pumped.

Water horsepower = \( \frac{(\text{Gallons per minute})(\text{total dynamic head in feet})}{3960} \)
Brake Horsepower - (BHP)
The horsepower of a power unit or of a pump unit as measured at the
driveshaft of the unit. When using the term brake horsepower, care must be
exercised to determine if it is the rated or actual horsepower of a power
unit or the power required by the pump. ‘Brake horsepower is a term used
for both the power unit output or the pump input. When determining the
power unit size for a pump, the brake horsepower needed can be computed
as follows:

\[ \text{RHP} = \frac{\text{WHP}}{(\text{pump efficiency})(\text{drive efficiency})} \]

Pump Efficiency -
The calculated efficiency of a pump unit including the pump bowl or
impeller loss, the screen loss and the pump shaft loss. The pump horsepower
is determined by comparing the pump HP input (or Brake horsepower) to the
computed WHP.

\[ \text{Pump efficiency} = \frac{\text{HP input}}{\text{WHP}} \]

Approximate average efficiencies of pump units are as follows:

- Centrifugal: 75%
- Deep well turbine: 75%
- Floating tailwater: 65%
- Submersible: 65%

Drive Efficiency -
The computed power loss from the motor or engine driveshaft to the
pump driveshaft. Some average drive efficiencies are as follows:

- Direct drive: 100%
- Right angle gear head: 95%
- Multiple V-belt: 90%
- Flat belt: 85%

Pumping Plant Efficiency -
The computed efficiency of the pump unit, the drive unit and the power
unit. It can be computed as follows:

\[ \text{Pumping plant efficiency} = \frac{\text{water horsepower (WHP)}}{\text{energy value of fuel}} \]

\[ \text{Pumping plant efficiency} = (\text{pump unit efficiency})(\text{drive unit efficiency})(\text{power unit efficiency}) \]
Horsepower Input - (HP input)

The heat or fuel energy (expressed in horsepower) consumed by the power unit of a pumping plant. It is also referred to as fuel, energy or thermal horsepower. Based on a national average pumping plant efficiency as shown below, the water horsepower (WHP) that can normally be expected from a fuel is as follows:

- One gallon L.P. gas - 19% efficient = 6.83 HP
- One gallon regular gasoline - 17.7% efficient = 8.63 HP
- One gallon diesel - 20.1% efficient = 10.92 HP
- 1,000 cubic feet (Mcf) natural gas - 17.0% efficient = 66.// HP
- One kilowatt electricity - 66% efficient = 0.88 HP

Example: One gallon of L.P. gas has 91,600 BTU of energy and one HP requires 2547 BTU's of energy, therefore, 91,600 = 35.96 HP per gallon of L.P. gas

A pumping plant powered by an L.P. gas engine can be expected to operate at 19% efficiency; therefore; (0.19)(35.96) = 6.83 expected water horsepower per gallon of L.P. gas.

Motor Horsepower Rating - (HP Rating)

The manufacturer's or nameplate horsepower. For electric motors, the HP rating is the continuous operating horsepower available to the pump. A 10 to 15 percent safety factor has been built into the electric motor, therefore, the HP rating is the actual HP available to the pump.

Engine Rated Horsepower - (HP Rating)

The manufacturer's or nameplate horsepower. For internal combustion engines, the HP rating is normally based on the bare engine dynometer horsepower under laboratory conditions while operating for short periods of time. To determine the actual HP available for work, the HP rating is reduced to compensate for continuous operating conditions, temperature, elevation and accessories, such as generator, alternator, water pump, fans, etc. The actual HP available for work is usually 20 to 30 percent less than the HP rating. Correction factors for power losses and allowances for internal combustion engines are as follows:

For continuous operation deduct 20 percent.
For each 1,000 feet above sea level deduct 3 percent.
For each 10° above 60° F deduct 1 percent.
For each accessory, such as a generator, waterpump, etc., deduct 5 percent.

Rated horsepower = Brake horsepower

\[
\frac{\text{100%-(sum of correction factors)}}{\text{100%}}
\]

Some actual corrected output horsepower for internal combustion engines are shown on the attached tables.
Some average pumping plant efficiencies are as follows:

L.P. gas engine  - 19.0%
Gasoline engine  - 17.7%
Diesel engine    - 20.1%
Natural gas      - 17.0%
Electricity     - 66.0%
GUIDELINES FOR MEASURING THE WATER LEVEL IN AN IRRIGATION WELL

There are several methods of measuring the water level in an irrigation well. Three methods that are practical and applicable for use by the SCS or the producer are discussed here.

WETTED TAPE METHOD

This is a simple inexpensive method of measuring the depth to static or standing water in a well. It is accurate and requires little equipment. Generally, it is limited to measuring the static water level and not the drawdown or pumping level. A disadvantage of this method is that the approximate depth to water must be known and is usually limited to wells less than 100 feet deep.

A lead weight is attached to a metal tape or cord. Two to four feet of the weighted end of the tape is coated with carpenter’s chalk before lowering the weight into the well. The weight is lowered to a point slightly below the water level and the line marked at the top of the casing or pump base. After removing the tape from the well, the distance from the mark at the top of the line to the wetted mark on the weighted end can be measured.

ELECTRIC SOUNDER OR ELECTRIC DEPTH GAUGE

This method will normally be used by SCS in New Mexico. It is probably the most used method since it is reasonably accurate, portable and versatile for most wells.

The electric depth gauge consists of a lead weighted contact electrode which is lowered into a well casing by a cable consisting of two electric wires. The cable is on a reel for convenience. The hub of the reel houses a battery and an ammeter or light. The cable is usually marked at five or ten foot intervals for determining the depth to water. As the electrode is lowered into the water, the water completes an electric circuit in the electrode and a reading is registered on the ammeter or the light comes on.

A common problem with using this method is getting the electrode into the well casing between the casing and the pump column pipe. If the pump base is not equipped for sounding, extreme care should be taken in trying to enter by some other means. Normally SCS technicians using the sounder should not attempt to sound a well unless it is properly equipped.

The most common hazard when sounding a well is getting the cable or electrode caught in the well. This is a common occurrence in wells using spacers between the column pipe and casing. Also, rough casing welds, slotted perforations, sharp edges or rough column pipe collars and crooked well holes can cause the cable or electrode to snag. If this occurs when an SCS technician sounds a well, he should cut the cable and secure it to the pump base to prevent damage to the pump. The cable can be recovered when the well is repaired. If several hundred feet of the cable are in the well when it snaps, the weight of the electrode and cable put a strain on the wire near the ground surface and only a small force is needed to break the cable, which should be avoided.

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Another hazard commonly occurs when the electrode is lowered to the depth of the pump and is pulled into the impellers. This can normally be eliminated by knowing the length of the column pipe in the well. Normally, if an SCS technician does not know the length of the column pipe he should not attempt to sound the well.

Occasionally a column pipe will leak water, or water from a shallow formation will leak into the casing. When this occurs, the leaking water will complete the electric circuit and show a current. Usually it is somewhat erratic and is shown by intermittent on and off current. It is always good to know approximately how deep the water level is to prevent getting incorrect readings.

AIR LINE METHOD

Generally the air line method is considered to be a permanent or semi-permanent installation for the primary purpose of providing the producer with water level data. It can, however, be used as a portable method, but would require considerable time to make the necessary measurements.

The air line consists of a small diameter pipe or tube (usually 1/8 to 3/8 inches in diameter) which extends from the top of the well to several feet below the lowest water level that would ever exist. The end of the tube is open. A pipe tee in the air line above the ground enables a pressure gauge and an air pump to be attached to the tube. The devise works on the principle that the air pumped into the tube will force air out of the submerged end and register a pressure on the gauge. This required pressure would be equal to the height of the water above the end of the submerged tube.

The exact length of the tube or pipe must be measured or known as it is placed in the well. If flexible or semi-flexible tubing is used, care must be used to make sure the tubing remains straight and does not shake or spiral inside the well casing. The fact that the air line must be air tight has presented some problems with plastic pipe in the past. The air line can also present problems when a pump is pulled for repair.

Pressure gauges are available that read directly in feet of water pressures, however, if the gauge reads in pounds per square inch the pressure can be converted to feet of water.

\[ L = \text{Length of air line} \]
\[ S = \text{Length of submerged line} \] (corresponding to gauge)
To use the air line method, air is pumped into the tubing until a maximum pressure is obtained on the gauge. This occurs when the entire tube is filled with air and overflow occurs out the submerged end. If the gauge reads in feet of water pressure, it then directly shows the submerged length from the length of tubing. If not, the PSI is converted to feet by multiplying PSI by 2.31.

To obtain depth to water, subtract the submerged length from the length of the tubing installed. This is true for the static depth of water or the pumping depth.

\[ d = L - S \]

\[ d = \text{Depth to Water, Ft.} \]

\[ L = \text{Depth to bottom of air line, Ft.} \]

\[ S = \text{Pressure Head (Ft.), represented by column of water equal to the submerged length of the air line}. \]

SCS technicians working with producers on pumping plant performance or efficiencies should encourage producers to install and use the "air line method" of determining the water level in wells.
HORSEPOWER DETERMINATIONS FROM WATTHOUR METERS

A quick and simple method of determining horsepower usage of an electric motor can be made with the information available from the watthour meter on the motor circuit. Typical electrically powered irrigation units feature watthour meters near the pump motor.

The watthour meter features a small revolving disc on the meter face. The revolutions per unit of time of the disc are in proportion to the amount of current being drawn by the electrical equipment being used. The formulas that can be used to easily field check the kilowatts and motor horsepower are:

\[ KW = 3.6 \times \text{meter disc revolutions} \times \text{meter constant (Kh)} \times \text{time in seconds} \]

After kilowatts are determined, the kilowatts can be converted to horsepower by using the following formula:

\[ HP = KW \times 1.34 \]

Figure 1 shows a typical watthour meter used on electric power units for irrigation systems. Much information is available from it but for determining kilowatts, one needs to be concerned with only two items: the revolving disc, and the meter constant. The meter constant is marked as Kh on the meter. The Kh stamped on the meter in Figure 1 is 28.8.
PROCEDURE FOR DETERMINING KILOWATTS AND HORSEPOWER FOR IRRIGATION PUMPING PLANTS

1. If the system is not operating at the time, start the pump motor and build pressure in the irrigation system to normal operating conditions.

2. If pumping from a well that has been shut down for several days, run the system long enough to stabilize the water level in the well.

3. If possible, turn off auxiliary motors such as injection pumps, and center pivot lower motors.

4. While facing the watthour meter, time 10 revolutions of the rotating disc. There is a darkened spot on the edge of the disc to aid in counting. Record the number of seconds it takes the disc to make 10 revolutions. This step should be repeated several times and the time averaged for accuracy.

5. Enter the average number of seconds from the test and the meter constant meter into the following equation:

   \[ Kw = \frac{3.6 \times 10 \text{ disc revolutions}}{\text{seconds}} \times \frac{\text{meter constant}}{1.34} \]

6. The horsepower that is being used is determined from the following formula:

   \[ Hp = Kw \times 1.34 \]

Current Transformers

At times a power company will install a current transformer ahead of the watthour meter. Current transformers are devices used to move only a proportion of the current through the meter. They are normally located at the end of the utility company's line and at the beginning of the irrigator's line. If a current transformer is used, a multiplier must be used with the Kw formula.

The current transformer will be marked with a number that indicates the ratio of current output. The numbers commonly observed will be 200:5, 400:5, 800:5 or 1600:5. To obtain the multiplier factor take the number before the colon and divide by the number following the colon.

Example: \[ 400:5 = \frac{400}{5} = 80 \]

The multiplier factor is 80.

As indicated above, if a current transformer is used, the multiplier factor must also be used in the Kw formula. In this example it would be 80. Where no current transformer is used, this multiplier factor is 1.

In some cases, the multiplier factor is marked on the face of the watthour meter.
Kilowatt and Horsepower Examples

The meter disc at one location required 25 seconds to make 10 revolutions. The meter constant, Kh, was 57.6 and no current transformer was used.

\[
\text{Kw} = \frac{3.6 \times 10 \times 57.6}{25} = 82.9
\]

\[
\text{Hp} = 89.2 \times 1.34 = 111.1
\]

The meter at a second location had a current transformer with an 800:5 current ratio: the multiplier factor is 800/5 = 160. Ten disc revolutions required 90 seconds and the meter constant, Kh, was 1.2.

\[
\text{Kw} = \frac{3.6 \times 10 \times 1.2 \times 160 \text{ (multiplier)}}{90} = 76.8
\]

\[
\text{Hp} = 76.8 \times 1.34 = 102.9
\]
GUIDELINES FOR DETERMINING THE AMOUNT OF NATURAL GAS BEING USED BY AN IRRIGATION MOTOR

There are several different types and brands of gas meters being used on natural gas powered irrigation motors in New Mexico. In order to accurately analyze an irrigation pumping plant and calculate pumping costs, the exact amount of natural gas being used by the motor must be determined. There are basically two types of meters being used, direct reading and pressure compensating.

DIRECT READING METER:

On a direct reading meter the check dial (which is the lowest dial and is usually 5, 10, 25 cubic feet) is in direct proportion to the lowest meter dial. Figure 1 is an example of a direct reading meter face. Ten revolutions of the "10" dial will move the "100" dial one revolution. If the check dial is not in proportion to the lowest meter dial, then the meter is not direct reading.

![Diagram of a gas meter]

Figure 1

To determine the Mcf (1,000 cubic feet) of natural gas being used, time how long it takes for the check dial to make a predetermined number of revolutions. Enter the number of revolutions and the time in seconds in the following equation:

\[ \text{Mcf per hour} = \frac{\text{Revolutions} \times \text{Cubic feet per revolution} \times (60 \text{ sec.}) \times (60 \text{ min}) \times 1 \text{ Mcf}}{\text{Time in seconds} \times 1,000 \text{ cubic feet} \times 1 \text{ hour}} \]

\[ = \frac{\text{Revolutions} \times \text{Cu. ft. per rev.}}{\text{Sec.}} \times (3.6) \]

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PRESSURE COMPENSATING METERS

Pressure compensating meters are usually marked on the face of the meter with a pressure reading. Sometimes the dial face is a different color than the rest of the meter. The check dial will not be in proportion to the lowest meter dial. Figure 2 is an example of a pressure compensating meter face.

![Figure 2](image)

To determine the Mcf of natural gas being used by the motor, time the check dial in the same manner as a direct reading meter. Use the same equation to calculate the Mcf per hour, then a pressure multiplier is applied to obtain the correct amount of gas being used. The correct pressure multiplier can be obtained from the attached table. The table is read by going down the gage pressure column until the correct pressure is found and then across to the appropriate correction multiplier.

EXAMPLE NO. 1

The meter that you are reading has a 10 lb pressure rating stamped on the red face dial. Five revolutions of the 10 cu. ft. check dial takes 98 seconds.

\[
\text{Mcf per hour} = \frac{(\text{Revolutions}) (\text{cu.ft.}) (3.6)}{\text{Seconds}}
\]

\[
= \frac{(5 \text{ rev.}) (10 \text{ cu.ft.}) (3.6)}{98 \text{ sec.}}
\]

\[
= 1.84 \text{ Mcf/hour}
\]

From table, pressure multiplier = 1.759

Corrected Mcf/hr. = 1.84 x 1.759 = 3.24 Mcf/hr.

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Equipment is available to check the gage pressure at the gas meter. A brass valve located on top of the meter covered with a screw cap provides a place to check the pressure. A needle attached to a pressure gage can be inserted through the leather or rubber valve located inside brass valve to get the pressure reading. These needles come in two sizes, a small and a large, depending on the size of the valve. Two pressure gages are required to check the different types of meters. A gage which registers from 0 to 30 ounces per square inch is used to check the 0 ounce meters. A gage which registers from 0 to 30 psi is used to check the meters which show a psi correction.

Some larger gas meters in New Mexico do not have a direct reading check dial on the face of the meter. Instead, these meters only have a total accumulated volume readout, similar in appearance to the odometer of a car. To get an accurate readout of gas usage on these meters, the volume readout should be recorded and then recorded again after at least 24 hours of running time has elapsed. The same general procedures are then used to calculate gas consumption.

Example No. 2

The gas meter you are reading has a totalizer readout only. Find the Mcf/Hr being used by the engine:

Totalizer reading on Tuesday, 8:00 A.M. = 10724.9 Cu. Ft.

Totalizer reading on Wednesday, 10:00 A.M. = 58564.9 Cu. Ft.

Total gas consumed = 58564.9
-10724.9
47840.0 Cu. Ft.

Total time elapsed = 26 Hours

MCF/HR = 47840 = 1.84 MCF/HR
26×1000

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</tbody>
</table>
STEPS FOR EVALUATING A PUMPING PLANT

1. Determine fuel consumption of power unit in:
   Gallons per hour for L.P. gas, gasoline or diesel
   Kilowatt hours per hour for electricity
   MCF (1,000 cubic feet) per hour for natural gas.

2. Determine pump discharge in gallons per minute (GPM)

3. Determine total dynamic head (TDH)
   \[ TDH = (\text{Drawdown water level in feet}) + (\text{Pump discharge pressure in feet}) \]

   NOTE: Pump column losses are usually so minor that they can be disregarded in this calculation.

4. Calculate the water horsepower output of the pumping plant (WHP).
   \[ \text{WHP} = \frac{(TDH)(GPM)}{3960} \]

5. Determine input horsepower of pumping plant based on fuel used.
   \[ \text{HP input} = (\text{Fuel consumed per hour}) \times (\text{HP of a unit of fuel at 100\% efficiency}) \]

6. Calculate overall pumping plant efficiency (O.E.)
   \[ \text{O.E.} = \frac{\text{WHP}}{\text{HP Input}} \]

7. Compare existing overall efficiency with standard obtainable efficiency for particular type of pumping plant.
   \[ \text{Percent of Standard Efficiency} = \frac{\text{O.E.} \times 100}{\text{Standard Efficiency}} \]

8. Determine irrigation water costs:
   \[ \frac{\$}{\text{AC-IN}} = \frac{\text{Fuel cost/hr}}{\text{Acre inches pumped per hour}} \]

-17-       Sept. 1984
9. Determine potential fuel savings per year if pumping plant was operating at obtainable standard efficiency.

Potential Annual Savings($) = \(\frac{(100 - \% \text{ of Std. Eff.})(\$/\text{Hr fuel cost})(\text{Annual hrs pumped})}{100}\)

10. Potential annual savings can also be calculated using efficiency increases obtainable thru increased water management or irrigation hardware alterations.

The attached worksheets should be used to record and compute evaluation data for natural gas and electric pumping plants.
PUMPING PLANT EVALUATION
ELECTRIC MOTOR

Landowner ________________________________________________ Date ____________

SWCD ___________________________ Field Office _______________________

Field No. __________________________ Well No. _________________________

Technician ________________________________________________

Make of Motor ___________ H. P. Rating ___________ RPM ____________

Electricity Consumption:

(1) \[(3.6) \times \text{(Kwh Factor)} \times \text{(Revolutions)} \times \text{(Multiplier)} \times \frac{\text{KWH/hr}}{\text{Time in Seconds}}\]

NOTE: The Kh Factor and the Multiplier are found on the face of the meter. In the absence of a multiplier on the meter, it is considered as \(\frac{1}{3}\).

Pump Efficiency:

(2) Well Yield ___________ GPM

(3) Total Pumping Lift --------------------------------- __________ ft.

(4) Discharge Head \(\text{psi} \times 2.31\) ----------------- __________ ft.

(5) Total Dynamic Head = T.D.H. ( #3 + #4) -------------- __________ ft.

(6) Output Horsepower = \[\text{TDH(#5)} \times \frac{\text{GPM(#2)}}{3960}\] = __________ H.P. out

(7) Input Horsepower = \[\text{KWH/hr(#1)} \times (1.34 \text{ HP/KW})\] = __________ H.P. in

(8) Overall Efficiency (O.E.) = \[\frac{\text{H.P. out(#6)}}{\text{H.P. in(#7)}} \times 100\] \(= \) __________ %

(9) Pump Efficiency = \[\frac{\text{O.E. (#8)}}{100} \times \text{Motor Eff. \(\frac{1}{3}\)}}\] \(= \) __________ %

1/ Standard Electric Motor Efficiencies

<table>
<thead>
<tr>
<th>Submersible</th>
<th>Vertical Hollow Shaft</th>
<th>V-Belt Drive (motor Only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-phase motors - 80%</td>
<td>10 - 100 H.P. - 90%</td>
<td>10 - 40 H.P. - 85%</td>
</tr>
<tr>
<td>Single phase motors - 75%</td>
<td>100 - 150 H.P. - 91%</td>
<td>40 - 125 H.P. - 89%</td>
</tr>
<tr>
<td></td>
<td>150 - 300 H.P. - 92%</td>
<td>125 - 130 H.P. - 92%</td>
</tr>
</tbody>
</table>

Determine a Standard Overall Efficiency (St.O.E.) using a standard pump efficiency of 75% and the motor efficiency used in #9.

-19-  Sept. 1984
(10) St.O.E. = (0.75) (motor eff. as a decimal) (100) = __________

(11) Percent of Standard Efficiency = O.E.(#8)x 100 = __________

Costs for Irrigation:

(12) Acre-Inches/hr pumped = GPM(#2) = _______ Acre-Inch/hr

(13) Energy Cost/hr = ___ KWH/hr(#1) X ___ Cost/KWH = $__________/hr.

(14) Energy Cost/Ac-In. = Cost/hr(#13) = $__________/Ac-In.

(15) Cost/Irrigation = ___ Cost/Ac-In(#14) X ___ In. Applied 2/ = $_____/Acre

(16) Est. Annual Energy Cost = Cost/hr(#13) X ___Annual hrs. pumped = $_____/yr.

Potential Cost Reduction:

(17) Potential Energy Reduction = 100 - ___% St. Eff. #11 = __________%

(18) Potential Energy Cost Reduction/hr =

(19) Potential Annual Reduction =

Recommendations:

-20-  Sept. 1984
PUMPING PLANT EVALUATION
NATURAL GAS ENGINE

Landowner ___________________________ Date __________

SWCD ___________________________ Field Office __________

Field No. ______________ Well No. ______________

Technician ___________________________

Make of Engine ______________ Model ______________ Size ______________

Engine RPM __________ Pump RPM __________ Gearhead Ratio __________

(1) Fuel Consumption = ( Cu.Ft. Used) (60 min/hr) (meter constant) 

                                  Time (min. to use Cu.Ft.)

= _______ Cu Ft /hr __________ Cu Ft /hr = _______ MCF/hr 1000

(2) Well yield __________ GPM

(3) Pumping Depth ___________________________ __________ Ft.

(4) Discharge Head (psi x 2.31) ____________ __________ Ft.

(5) Total Dynamic Head (#3 + #4) ___________ __________ Ft.

(6) Output Horsepower = TDH (#5) x GPM (#2) = _______ Hp out 3960

(7) Input Horsepower = _______ MCF/hr (#1) x 392.77 = _______ HP in

(8) Overall Efficiency (O.E.) = _______ H.P. out X 100 = _______ H.P. in

Determine percent of standard by comparing the O.E. with standard efficiency of 17 percent:

(9) Percent of Standard Efficiency = _______ O.E. (#8) X 100 = _______ % 17

Costs for Irrigation

(10) Fuel Cost/hr = _______ MCF/hr (#1) X _______ Fuel Cost/MCF = $ _______/hr

(11) Acre Inches per Hour = _______ GPM (#2) = _______ Ac-In/hr 450

-21-    Sept. 1984
(12) Fuel cost/Ac-In = \[
\frac{\text{Cost/hr (#10)}}{\text{Ac-In/hr (#11)}} = \frac{\text{$___}}{\text{Ac-In}}
\]
(13) Cost/Irrigation = \[
\frac{\text{Cost/Ac-In (#12)}}{\text{Inches Applied (#1)}} = \frac{\text{$___}}{\text{In/Acre}}
\]
(14) Est. Annual Energy Cost = \[
\frac{\text{Cost/hr (#10)}}{\text{Annual hrs pumped (#16)}} = \frac{\text{$___}}{\text{yr}}
\]

\[
\text{Inches/Irrigation Applied:}
\]
\[
\text{Furrows} = \frac{\text{GPM (#2)}}{\text{FL/row}} \times \frac{\text{In/row}}{\text{No. rows}} \times \text{hrs/set X 1161.6 = } \text{___ inches}
\]
\[
\text{Sprinkler} = \frac{\text{GPM (#2)}}{\text{450}} \times \text{hrs/revolution = } \text{___ inches}
\]

Potential Cost Reduction

(15) Potential fuel reduction = 100% - \[
\text{___} \% \text{ Standard (#9)} = \text{___} \%
\]
(16) Potential fuel cost reduction/hr = \[
\frac{\text{Cost/hr (#10)}}{\text{___} \% \text{ (decimal #15)}} = \frac{\text{$___}}{\text{hr}}
\]
(17) Potential Annual Reduction = \[
\frac{\text{$___}}{\text{hr (#16)}} \times \text{annual hours of pumping} = \text{$___}
\]

RECOMMENDATIONS:
PUMPING PLANT EVALUATION
ELECTRIC MOTOR

Landowner ____________ Date ____________

SWCD ________________ Field Office ________________

Field No. ________________ Well No. ________________

Technician ________________

Make of Motor GE H. P. Rating 80 RPM 1760

Electricity Consumption:

(1) \( (3.6) \left( \frac{28.8}{10 \text{ revolutions}} \right) \left( \frac{1 \text{ multiplier}}{17.1 \text{ Time in Seconds}} \right) = 60.6 \text{ KWH/hr} \)

NOTE: The Kh Factor and the Multiplier are found on the face of the meter. In the absence of a multiplier on the meter, it is considered as 1.

Pump Efficiency:

(2) Well Yield 840 GPM

(3) Total Pumping Lift ________________ 140 ft.

(4) Discharge Head 42 psi x 2.37 ________________ 97 ft.

(5) Total Dynamic Head - T.D.H. ( #3 + #4) ________________ 237 ft.

(6) Output Horsepower = \( \frac{25}{15} \times 15 \times 840 \text{ GPM(#2)} = 50.3 \text{ H.P. out} \)

\( \frac{\text{KWH/HR(#1)}}{1.34 \text{ HP/KW}} = 81.2 \text{ H.P. in.} \)

(7) Input Horsepower = \( 60.6 \text{ KWH/HR(#1)} \) (1.34 HP/KW) = 81.2 H.P. in.

(8) Overall Efficiency (O.E.) = \( \frac{50.3 \text{ H.P. out(#6)}}{81.2 \text{ H.P. in(#7)}} = 62 \) %

(9) Pump Efficiency = \( \frac{62 \text{ O.E. #8)(100)}}{17.1} = 68.9 \) %

\( \frac{\text{Motor Eff.}}{17.1} \)

1/ Standard Electric Motor Efficiencies

<table>
<thead>
<tr>
<th>Submersible</th>
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<th>V-Belt Drive (motor Only)</th>
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<td>10 - 40 H.P. - 88%</td>
</tr>
<tr>
<td>Single phase motors - 75%</td>
<td>100 - 150 H.P. - 91%</td>
<td>40 - 125 H.P. - 89%</td>
</tr>
<tr>
<td></td>
<td>150 - 300 H.P. - 92%</td>
<td>125 - 130 H.P. - 92%</td>
</tr>
</tbody>
</table>

Determine a Standard Overall Efficiency (St.O.E.) using a standard pump efficiency of 75% and the motor efficiency used in #9.

-23-                     Sept. 1984
(10) St.O.E. = (0.75) (motor eff. as a decimal) (100) = 67.5 \% 

(11) Percent of Standard Efficiency = \frac{62 \text{ O.E.} (#8) \times 100}{67.5 \text{ St.O.E.} (#10)} = 91.9 \% 

Costs for Irrigation:

(12) Acre-Inches/hr pumped = \frac{840 \text{ GPM} (#2)}{450} = 1.87 \text{ Acre-Inch/hr} 

(13) Energy Cost/hr = \frac{62.6 \text{ KWH/hr} (#1)}{8.08 \text{ Cost/KWH}} = $4.85 /\text{hr}.

(14) Energy Cost/Ac-In. = \frac{4.85 \text{ Cost/hr (#13)}}{1.87 \text{ Ac-In/hr (#12)}} = $2.59 /\text{Ac-In.} 

(15) Cost/Irrigation = \frac{\text{Cost/Ac-In} (#14) \times \text{In. Applied} 2/}{\text{In. Applied/Acre}} = $\_

(16) Est. Annual Energy Cost = \frac{4.85 \text{ Cost/hr (#13)} \times 2500 \text{ Annual hrs. pumped}}{12/12.5} = $--- /\text{yr.} 

2/ Inches Applied/Irrigation:

\begin{align*}
\text{Furrows} &= \frac{\text{GPM} (#2) \times \text{hrs/set} \times 1161.6}{\text{ft/row} \times \text{in/row} \times \text{No. rows}} = \_
\text{In. applied} \\
\text{Sprinkler} &= \frac{\text{GPM} (#2) \times \text{hrs/Revolution}}{450 \times \text{Ac. Irrigated}} = \_
\text{In. applied}
\end{align*}

Potential Cost Reduction:

(17) Potential Energy Reduction = 100 - 91.9 \% \text{ St. Eff. #11} = 8.1 \% 

(18) Potential Energy Cost Reduction/hr = \frac{4.85 \text{ Cost/hr (#13)} \times 0.08}{\text{Potential Reduction (#17 as decimal)}} = $0.39 /\text{hr.} 

(19) Potential Annual Reduction = \frac{-0.39 \text{ Cost Reduction/hr (#18)} \times 2500 \text{Annual hrs. pumped}}{9.75 \text{ /year}} = 

RECOMMENDATIONS:
PUMPING PLANT EVALUATION
NATURAL GAS ENGINE

Landowner ____________ EXAMPLE ____________ Date ____________

SWCD ________________ Field Office ________________

Field No. ______________ Well No. ________________

Technician ______________

Make of Engine FORD Model V-8 Size 534

Engine RPM 1800 Pump RPM 1800 Gearhead Ratio 1:1

(1) Fuel Consumption = (285 Cu. Ft. Head) (60 min/hr) (1 meter constant)
              10 Time (min. to use Cu.Ft.)

              = 1710 Cu.Ft./hr 1710 Cu.Ft./hr = 1.71 MCF/hr
              1000

(2) Well yield 800 GPM

(3) Pumping Depth ______________ 250 Ft.

(4) Discharge Head (psi x 2.31)

              65 x 2.31 = 150 Ft.

(5) Total Dynamic Head (#3 + #4) ______________ 400 Ft.

(6) Output Horsepower = 400TDH (#5) x 800 GPM (#2) = 80.8 Hp out

              3960

(7) Input Horsepower = 1.71 MCF/hr (#1) X 392.77 = 671.6 HP in

(8) Overall Efficiency (O.E.) = \( \frac{80.8 \text{ H.P. out}}{671.6 \text{ H.P. in}} \) X 100 = 12%

Determine percent of standard by comparing the O.E. with standard efficiency of 17 percent:

(9) Percent of Standard Efficiency = \( \frac{12 \text{ O.E. (#8)}}{17} \times 100 = 71\% \)

Costs for Irrigation

(10) Fuel Cost/hr = 1.71 MCF/hr (#1) X 3.20 Fuel Cost/MCF = 5.547/hr

(11) Acre Inches per Hour = \( \frac{800 \text{ GPM (#2)}}{450} \) = 1.78 Ac-In/hr

Sept. 1984
(12) Fuel cost/Ac-In = \( \frac{5.47 \text{Cost/hr (\#10)}}{1.78 \text{Ac-In/hr (\#11)}} = \$3.07 \text{/Ac-In} \)

(13) Cost/Irrigation = $____/Ac-In (\#12) X _____ Inches Applied 1/

= $_____/Acre

(14) Est. Annual Energy Cost = $5.47/hr (\#10) X 3000 Annual hrs pumped

= $16810/yr

1/ Inches/Irrigation Applied:

Furrows = \( \frac{\text{GPM (#2)}}{\text{Ft/run}} \times \frac{\text{hrs/set}}{\text{X} 1161.6} = \) inches

Sprinkler = \( \frac{\text{GPM (#2)}}{\text{In/row}} \times \frac{\text{hrs/revolution}}{\text{X} 450} = \) inches

\text{acres irrigated}

Potential Cost Reduction

(15) Potential fuel reduction = 100% - \( \frac{71}{2} \% \) Standard (\#9) = 29 %

(16) Potential fuel cost reduction/hr = \( \frac{5.47 \text{hr (\#10)}}{29 \%} \times (\text{decimal \#15}) \)

= $1.59/\text{hr}

(17) Potential Annual Reduction = $1.59/hr (\#16) X 3000 annual hours

of pumping = $4770

RECOMMENDATIONS:

-26- Sept. 1984
EXAMPLE

If the electricity cost at Deming is 9¢/KW-HR, the average fuel cost at Deming is $.189/AC-FT of Lift. For a 100 Ft. Lift, fuel costs would then be $18.90/AC-FT. of water pumped.
EXAMPLE

If the natural gas cost at Clovis is $4.20/MCF, the average fuel cost at Clovis is $.128/AC-FT/FT of lift. For a 300 ft. lift, fuel costs would then be $38.40/AC-FT of water pumped.
FUEL COSTS FOR ELECTRIC PUMPING PLANTS
WITH VARIOUS COMBINED PUMP AND GEARHEAD EFFICIENCIES

CORRECTION FACTORS FOR VARIOUS MOTOR EFFICIENCIES

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<tr>
<td>80%</td>
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<tr>
<td>75%</td>
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EXAMPLE

GIVEN:

An electric pumping plant is operating with a motor efficiency of 90% and a pump efficiency of 60%. The cost of electricity is $0.10/KW-HR.


SOLUTION: Enter proceeding graph along bottom at $.10. Proceed upward to 60% line. Read on left scale - $.188/AC-FT/FT-Lift. If motor efficiency was 95%, multiply answer by correction factor (C.F.) of .95.

(.95 x $.188 = $.179)
FUEL COSTS FOR NATURAL GAS PUMPING PLANTS
WITH VARIOUS COMBINED PUMP AND GEARHEAD EFFICIENCIES

CORRECTION FACTORS FOR VARIOUS ENGINE FUEL EFFICIENCIES

<table>
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<tr>
<th>EFFICIENCY</th>
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<td>15%</td>
<td>1.67</td>
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<td>20%</td>
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<tr>
<td>25%</td>
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<tr>
<td>30%</td>
<td>0.83</td>
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</table>

GAS COST - $/MCF

$3.00 $3.50 $4.00 $4.50 $5.00 $5.50 $6.00
EXAMPLE

GIVEN:

A natural gas pumping plant is operating with an engine efficiency of 25%. The combined pump and gearhead efficiency is 60%. The natural gas cost is $4.00/MCF.


SOLUTION. Enter proceeding graph along bottom at $4.00. Proceed upward to 60% line. Read on left scale - $.186/AC-FT/FT-Lift. If the engine efficiency drops to 15%, multiply the answer by a correction factor (C.F.) of 1.67. (1.67 x $.186 = $.311)
OUTPUT HORSEPOWER
FOR VARIOUS AUTOMOTIVE-TYPE INTERNAL COMBUSTION ENGINES
Corrected For Continuous Duty
And 4000' Elevation

<table>
<thead>
<tr>
<th>MFG</th>
<th>TYPE</th>
<th>CID</th>
<th>ENGINE RPM AND GEAR HEAD RATIO</th>
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<td>V8</td>
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<tr>
<td>GMC</td>
<td>V-12</td>
<td>637</td>
<td>115</td>
</tr>
</tbody>
</table>

For engines not on this chart: Continuous duty HP, at 1760 rpm, corrected to 4000' feet elevation = CID x 0.2

Example: CID = 500
HP @ 1760 rpm = 500 x .2 = 100 HP

-33-  Sept. 1984
### OUTPUT HORSEPOWER

**FOR VARIOUS INDUSTRIAL-TYPE ENGINES**

*Corrected For Continuous Duty
And 4000' Elevation*

<table>
<thead>
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-34- Sept. 1984
# OUTPUT HORSEPOWER

**FOR VARIOUS INDUSTRIAL-TYPE ENGINES**

Corrected For Continuous Duty
And 4000' Elevation

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**NOTE:** I - Turbocharged - Intercooled
T - Turbocharged

-35-  Sept. 1984
## OUTPUT HORSEPOWER

**FOR VARIOUS INDUSTRIAL-TYPE ENGINES**

*Corrected For Continuous Duty And 4000' Elevation*

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EXAMPLE No. 1

Pumping Plant Performance Using An Electric Motor

Problem:
The power unit for a center-pivot sprinkler is an electric motor rated at 80 horsepower. It is connected directly to an 8 inch pump. The well is located at the pivot and produces 840 gpm from a water level of 140 feet and operates with 42 psi at the pump. The disk on the electric motor was revolving at a rate of 10 revolutions in 17.1 seconds. The K, factor on the meter is 28.8 and the electricity cost is 8¢ per kw hour.

Solution:
1. TDH = (lift) + (discharge pressure)
   a. lift = 140 feet
   b. discharge pressure = (42 psi)(2.31) = 97.02 feet
   c. TDH = 140' + 97' = 237 feet

2. WHP = \( \frac{TDH \times GPM}{3960} \)
   = \( \frac{(237)(840)}{3960} \)
   = 50.3 HP

3. Fuel consumption = \( \frac{(3.6)(kh)(R)}{t} \)
   = \( \frac{(3.6)(28.8)(10)}{17.1} \)
   = 60.6 Kw per hour

4. Input HP = \( \frac{KWH/HR}{HP/KW} \) = 60.6 x 1.34 = 81.2 HP

5. Overall Efficiency = \( \frac{WHP \times 100}{HP \text{ input}} \)
   = \( \frac{50.3 \times 100}{81.2} \)
   = 62%

6. Cost per acre inch:
   a. Fuel cost per hour = (60.6Kw)(8¢ per Kw) = $4.85
   b. Acre inches pumped = 840 gpm = 1.87 acre inch per hour
   c. Cost per acre inch = \( \frac{Cost \text{ per hour}}{Acre \text{ inches pumped per hour}} \)
   = \( \frac{4.85}{1.87} \)
   = $2.59 per acre inch

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EXAMPLE No. 2
Pumping Plant Performance Using Gas Engine

Problem:
The power unit for a pumping plant is a natural gas engine. The gas meter was timed for 10 minutes and used 285 cubic feet of gas. The natural gas cost is $3.20 per MCF. The 8 inch pump discharges 800 gpm into a closed pipeline at 65 psi. The static water level in the well is 240 feet and the drawdown with the pump operating is 10 feet.

Solution:
1. TDH:
   a. pumping lift = 240+10 = 250 feet
   b. discharge pressure = (65 psi)(2.31) = 150.2 feet
   c. TDH = lift + discharge pressure = (250')+(150') = 400 feet

2. WHP = \( \frac{(TDH)(GPM)}{3560} = \frac{(400)(800)}{3560} = 80.8 \text{ HP} \)

3. Measured fuel = \( \frac{(285 \text{ cubic feet}) \times (60 \text{ min/hr})}{10 \text{ min}} \)
   = 1710 cubic feet or 1.71 MCF/hr

4. Input HP = (MCF/hr)(HP value of fuel) = (1.71)(392.77) = 671.6 HP

5. Overall efficiency (O.E.) = \( \frac{WHP}{\text{HP input}} = \frac{80.8 \text{ HP}}{671.6} = 12\% \)

6. Determine percent of standard efficiency by comparing overall efficiency with standard efficiency of 17%.
   Percent of Standard Efficiency = \( \frac{(O.E)(100)}{17} = \frac{12 \times 100}{17} = 71\% \)

7. Cost per acre inch:
   a. Fuel cost per hour = \( (1.71 \text{ MCF used}) \times (3.20 \text{ per MCF}) = 5.47/\text{hr} \)
   b. Acre inches applied = \( \frac{800 \text{ gpm}}{450 \text{ gpm per cfs}} = 1.78 \text{ acre-in per hour} \)
   c. Cost per acre inch = fuel cost per hour \( \frac{5.47}{1.78} = 3.07 \text{ per acre inch} \)

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EXAMPLE No. 3

Determining Electric Motor Size

Problem:
Plans are to install a 10 inch turbine pump with a direct drive electric motor on a well producing 1150 gpm from a water level of 213 feet. The pump will tie into a center pivot at the well and operate the pivot at 40 psi.

Solution:

1. Find TDH
   a. Lift = 213 feet
   b. discharge pressure = (40 psi)(2.31) = 92.4 ft
   c. IUH = (213)+(92.4) = 305.4 ft

2. Find WHP = \( \frac{(TDH)(gpm)}{3960} = \frac{(305.4 \text{ ft})(1150 \text{ gpm})}{3960} = 88.7 \text{ WHP} \)

3. Determine HP input of pump:
   Average efficiency of turbine pump is 75%

   HP input of pump = \( \frac{\text{WHP}}{\text{Pump eff.}} = \frac{88.7}{0.75} = 118.3 \text{ HP} \)
EXAMPLE No. 4

Determining Internal Combustion Engine Size

Problem:
Plans are to equip a well with an 8 inch turbine pump and right angle gear head coupled to an internal combustion engine using natural gas. A well test shows the static water level to be 133 feet. The drawdown was 5 feet when pumping 800 gpm. The pump will supply water to a center-pivot sprinkler at the pump operating at 60 psi.

Solution:

1. Find TDH:
   a. \( \text{lift} = (133') + (5') = 138 \text{ feet} \)
   b. \( \text{discharge pressure} = (2.31)(60 \text{ psi}) = 138.6 \text{ feet} \)
   c. \( \text{TDH} = \text{lift} + \text{discharge pressure} \\
   = (138') + (138.6') = 276.6 \text{ feet} \)

2. Find WHP:
   \( \text{WHP} = (276.6 \text{ ft})(800 \text{ gpm}) = 55.9 \text{ HP} \)

3. Find necessary output horsepower of internal combustion engine:
   \( \text{turbine pump efficiency} = 75\% \)
   \( \text{Rt. angle gear head efficiency} = 95\% \)
   \( \text{Output HP of Engine} = \frac{\text{WHP}}{\text{Pump Eff. x Drive Eff.}} \\
   = 55.9 \times \frac{1}{.75 \times .95} \\
   = 78.4 \text{ HP} \)

An internal combustion engine can now be chosen from the attached horsepower charts that will deliver the necessary horsepower at the desired running speed.
EXAMPLE NUMBER 5

Location: Estancia Field Office

Source of Irrigation Water: Well

Pumping Depth: 180 feet

Well Output: 850 GPM

Crop: Corn

Acres Irrigated: 125

Fuel Type: Electric

Type of Irrigation System: Circular sprinkler (65 percent efficiency)

Pump Discharge Pressure: 60 PSI (139 feet)

Total Pumping Cost: 20¢/AC-FT/FT of lift

Usual Gross ACIR for corn: 2.1 AC-FT/acre (from CU tables at 65 percent efficiency)
Find: The difference in pumping costs if 10 inch diameter plastic pipe is installed instead of 8 inch diameter plastic pipe. Will the 10 inch diameter plastic pipe pay for itself within 3 years?

Solution:

The first things we need to know is the difference in friction loss between 8 inch and 10 inch diameter pipe.
From the Engineering Field Manual we find the following friction loss data:

850 GPM in 8 inch diameter plastic pipe - 11.9 feet/1,000 feet.

850 GPM in 10 inch diameter plastic pipe - 3.7 feet/1,000 feet.

The difference therefore is (11.9 - 3.7) 8.2 feet/1,000 feet.

If we have 1,800 feet of pipeline, the 8 inch diameter pipe will produce an extra head of (1.8 X 8.2) = 14.8 feet on the pumping plant at all times.

The total pumping cost increase is computed as follows: (extra head in feet) X (cost/AC-FT/FT of lift) X (acre feet water needs per acre) X (total acres irrigated)

14.8 X 20¢ X 2.1 X 125 = $777.00 per year.

The 8 inch diameter pipeline therefore costs the farmer $777.00 per year in extra pumping costs.

Can this pumping cost savings offset the extra initial cost of 10 inch diameter pipeline in 3 years?
The following are the installed costs of the pipeline used in this example:

10 inch diameter - $4.00/ft.

8 inch diameter - $3.20/ft.

The difference between the 10 inch and the 8 inch diameter is therefore 80¢/ft.

The total extra cost of installing the 1,800 feet of 10 inch diameter pipe is (1,800 X $.80) = $1,440.

Without any amortization considered, the 10 inch diameter pipeline would pay for itself in (1440/777) = 1.85 years.
EXAMPLE NUMBER 6

Location: Deming Field Office

Source of Irrigation Water: Well

Pumping Depth: 120 feet

Well Output: 1200 GPM

Crop: Cotton

Acres Irrigated: 160

Fuel Type: Electric

Type of Irrigation System: Surface Furrows (estimated 50% efficiency)

Total head on pump: 142 feet

Fuel Cost: $.20/AC-FT/FT of Lift

Usual Gross CU for Cotton: 4.8 AC-FT (From CU tables at 50% efficiency)

Find: Pumping cost savings per year if efficiency can be increased by 15% to 65%.

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Solution:

The fuel cost is $.20 per acre-foot per ft. of lift.

Since the crop needs 4.8 AC-FT at 50% efficiency, the crop needs at 65% efficiency are $\frac{4.8 \times 0.5}{0.65} = 3.7$ AC-FT.

The difference in water requirements is $(4.8 - 3.7) = 1.1$ AC-FT.

The pumping cost saved per acre per foot of lift is:

$(.20)(1.1) = .22$

If 160 acres are irrigated, and the total head is 142 feet, the fuel cost saved is: $(.22)(160)(142) = $4,998.40 per year or $\frac{4,998.40}{160} = 31.24$ per acre per year