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 system.

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

1. Current efficiency status of irrigation pumping plant.

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.

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.

$$\text{Water horsepower-WHP} = \frac{(\text{Gallons per minute})(\text{total dynamic head in feet})}{3960}$$

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:

$$BHP = \frac{WHP}{(\text{pump efficiency})(\text{drive efficiency})}$$

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:

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

Pumping plant efficiency = (pump unit efficiency)(drive unit efficiency)(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	= 66.77 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, $\frac{91,600}{2547}$ = 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^{o} above 60^{o} F deduct 1 percent.
For each accessory, such as a generator, waterpump, etc., deduct 5 percent.

$$\text{Rated horsepower} = \frac{\text{Brake horsepower}}{100\%-(\text{sum of correction factors})}$$

Some actual corrected output horsepowers for internal combustion engines are shown on the attached tables.

Some average pumping plant efficiences 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 snags, 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.

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.

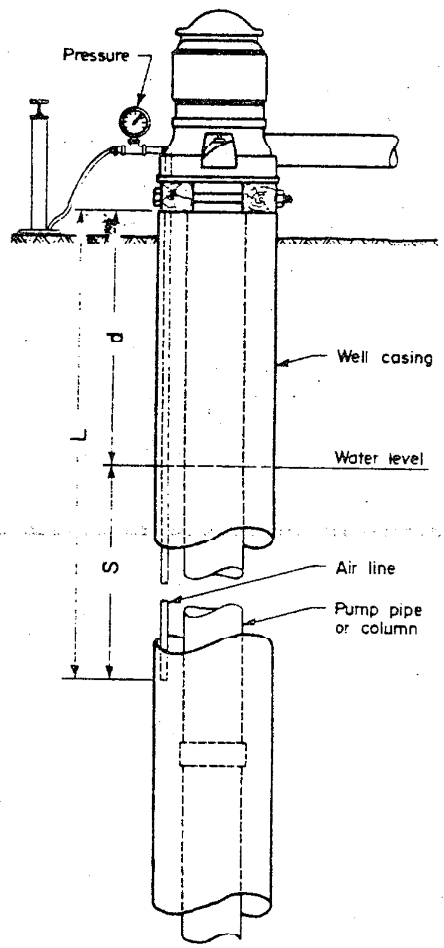
AIR LINE METHOD

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 diamter 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 – Length of air line
S = Length of submerged line
(corresponds 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 = Depth to Water, Ft.

L = Depth to bottom of air line, Ft.

S = 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:

$$KW = \frac{3.6 \text{ X meter disc revolutions X meter constant (Kh)}}{\text{time in seconds}}.$$

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

$$Hp = KW \text{ X } 1.34$$

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.

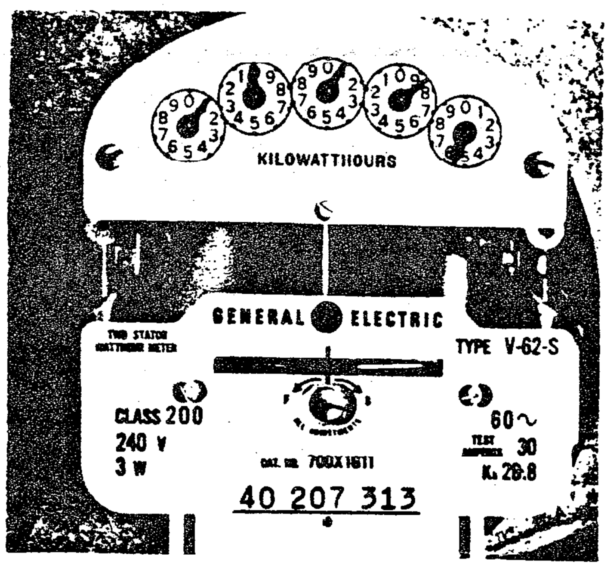


FIGURE 1

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 tower 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:

$$Kw = 3.6 \times \frac{10 \text{ disc revolutions}}{\_\_\_\_\_\_ \text{ seconds}} \times \_\_\_\_\_\_ \text{(meter constant)}.$$

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.

$$Kw = 3.6 \times \frac{10}{25} \times 57.6 = 82.9$$

$$Hp = 89.2 \times 1.34 = 111.1$$

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.

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

$$Hp = 76.8 \times 1.34 = 102.9$$

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.

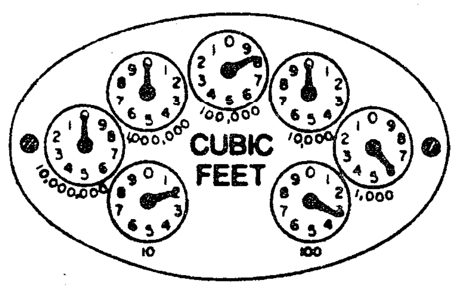


Figure 1

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:

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

$$= \frac{(\text{Rev.})\ (\text{Cu. ft. per rev.})\ (3.6)}{(\text{Sec.})}$$

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.

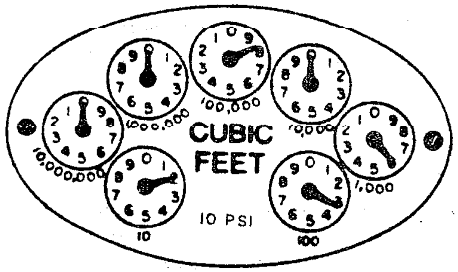


Figure 2

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.

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 8 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.

$$\begin{array}{r} 58564.9 \\ -\underline{10724.9} \\ 47840.0 \end{array} \text{ Cu. Ft.}$$

Total time elapsed = 26 Hours

$$\text{MCF/HR} = \frac{47840}{26 \times 1000} = 1.84 \text{ MCF/HR}$$

PRESSURE CORRECTION TABLE FOR USE IN ADJUSTING POSITIVE METER DELIVERIES BASED ON 12.85# ABSOLUTE OR 12.60# ATMOSPHERIC PRESSURE + 4 OUNCES

$$\text{MULTIPLIER} = \frac{\text{12.60\# + Gage Pressure}}{\text{12.85\#}}$$

Gage Pressure	Pressure Correction Multiplier	Gage Pressure	Pressure Correction Multiplier	Gage Pressure	Pressure Correction Multiplier
4 oz.	1.000	8¼	1.623	28½ lbs.	3.198
5	1.005	8½	1.642	29	3.237
6	1.010	8 3/4	1.661	29 1/2	3.276
7	1.015	9	1.681	30	3.315
8	1.019	9¼	1.700	30½	3.354
9	1.024	9½	1.720	31	3.393
10	1.029	9 3/4	1.739	31½	3.432
11	1.034	10	1.759	32	3.471
12	1.039	10½	1.798	32½	3.510
13	1.044	11	1.837	33	3.549
14	1.049	11½	1.875	33½	3.588
15	1.054	12	1.914	34	3.626
16	1.058	12½	1.953	34½	3.665
17	1.063	13	1.992	35	3.704
18	1.068	13½	2.031	35½	3.743
19	1.073	14	2.070	36	3.782
20	1.078	14½	2.109	36½	3.821
1½ lbs.	1.097	15	2.148	37	3.860
1 3/4	1.117	15½	2.187	37½	3.899
2	1.136	16	2.226	38	3.938
2¼	1.156	16½	2.265	38½	3.977
2½	1.175	17	2.304	39	4.016
2 3/4	1.195	17½	2.342	39½	4.054
3	1.214	18	2.381	40	4.093
3¼	1.233	18½	2.420	40½	4.132
3½	1.253	19	2.459	41	4.171
3 3/4	1.272	19½	2.498	41½	4.210
4	1.292	20	2.537	42	4.249
4¼	1.311	20½	2.576	42½	4.288
4½	1.331	21	2.615	43	4.327
4 3/4	1.350	21½	2.654	43½	4.366
5	1.370	22	2.693	44	4.405
5¼	1.389	22½	2.732	44½	4.444
5½	1.409	23	2.770	45	4.482
5 3/4	1.428	23½	2.809	45½	4.521
6	1.447	24	2.848	46	4.560
6¼	1.467	24½	2.887	46½	4.599
6½	1.486	25	2.926	47	4.638
6 3/4	1.506	25½	2.965	47½	4.677
7	1.525	26	3.004	48	4.716
7¼	1.545	26½	3.043	48½	4.755
7½	1.564	27	3.082	49	4.794
7 3/4	1.584	27½	3.121	49½	4.833
8	1.603	28	3.160	50	4.872

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 = (Drawdown water level in feet) + (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).

   $$WHP = \frac{(TDH)(GPM)}{3960}$$

5. Determine input horsepower of pumping plant based on fuel used.

   HP input = (Fuel consumed per hour) X (HP of a unit of fuel at 100% efficiency)

6. Calculate overall pumping plant efficiency (O.E.)

   $$O.E. = \frac{WHP}{HP\ Input}$$

7. Compare existing overall efficiency with standard obtainable efficiency for particular type of pumping plant.

   $$\text{Percent of Standard Efficiency} = \frac{O.E. \times 100}{\text{Standard Efficiency}}$$

8. Determine irrigation water costs:

   $$\$/AC\text{-}IN = \frac{\text{Fuel cost/hr}}{\text{Acre inches pumped per hour}}$$

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

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

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) (Kh Factor) (Revolutions) (Multiplier) / ____ Time in Seconds = _____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 __________ GPM

(3) Total Pumping Lift -------------------------------- __________ft.

(4) Discharge Head ____ psi x 2.31 -------------------- __________ft.

(5) Total Dynamic Head - T.D.H. (#3 + #4) ------------- __________ft.

(6) Output Horsepower = TDH(#5)X GPM(#2) / 3960 = __________H.P. out

(7) Input Horsepower = ____KWH/hr(#1) (1.34 HP/KW) = ________H.P. in

(8) Overall Efficiency (O.E.) = H.P. out(#6) (100) / H.P. in(#7) = ______________%

(9) Pump Efficiency = O.E. (#8) (100) / Motor Eff. 1/ = ________________%

1/ Standard Electric Motor Efficiencies

Submersible	Vertical Hollow Shaft	V-Belt Drive (motor Only)
3-phase motors - 80%	10 - 100 H.P. - 90%	10 - 40 H.P. - 88%
Single phase motors-75%	100 - 150 H.P. - 91%	40 -125 H.P. - 89%
	150 - 300 H.P. - 92%	125 -130 H.P. - 92%

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

(10) St.O.E. = (0.75) (motor eff. as a decimal) (100) = ______________%

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

Costs for Irrigation:

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

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

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

2/ Inches Applied/Irrigation:

Furrows = $\frac{(\quad \text{GPM \#2}) (\quad \text{hrs/set}) (1161.6)}{(\quad \text{ft/run}) (\quad \text{In/row}) (\quad \text{No. rows})}$ = ___________In. applied

Sprinkler = $\frac{(\quad \text{GPM \#2}) (\quad \text{hrs/Revolution})}{(450) (\quad \text{Ac. Irrigated})}$ = _______________In. applied

Potential Cost Reduction:

(17) Potential Energy Reduction = 100 - _____% St. Eff. #11 = ___________%

(18) Potential Energy Cost Reduction/hr =

_____Cost/hr(#13) x _____Potential Reduction (#17 as decimal) = $_____/hr.

(19) Potential Annual Reduction =

____Cost Reduction/hr(#18) X ______Annual hrs. pumped = $_________/year

R E C O M M E N D A T I O N S:

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 = $\frac{(\quad \text{Cu.Ft. Used}) (60 \text{ min/hr}) (\quad \text{meter constant})}{\text{Time (min. to use Cu.Ft.)}}$

= ________ Cu.Ft./hr $\frac{\text{\_\_\_\_\_ Cu.Ft./hr}}{1000}$ = ________ MCF/hr

(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 = $\frac{\text{TDH (\#5) x} \quad \text{GPM (\#2)}}{3960}$ = ________ Hp out

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

(8) Overall Efficiency (O.E.) = $\frac{\text{H.P. out}}{\text{H.P. in}}$ X 100 = __________

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

(9) Percent of Standard Efficiency = $\frac{\text{O.E. (\#8) X 100}}{17}$ = ________ %

Costs for Irrigation

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

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

(12) Fuel cost/Ac-In = $\frac{\text{Cost/hr (\#10)}}{\text{Ac-In/hr (\#11)}}$ = $__________/Ac-In

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

= $_________/Acre

(14) Est. Annual Energy Cost = $_____/hr (#10) X_______Annual hrs pumped

= $________/ yr

1/ Inches/Irrigation Applied:

Furrows = $\frac{\text{\_\_\_\_ GPM (\#2) X \_\_\_\_ hrs/set X 1161.6}}{\text{\_\_\_\_ Ft/run X \_\_\_\_ In/row X \_\_\_ No. rows}}$ = ______inches

Sprinkler = $\frac{\text{\_\_\_\_ GPM (\#2) X \_\_\_\_ hrs/revolution}}{\text{450 X \_\_\_\_ acres irrigated}}$ = ______inches

Potential Cost Reduction

(15) Potential fuel reduction = 100% - _____% Standard (#9) = ________%

(16) Potential fuel cost reduction/hr = $____/hr (#10) X ______% (decimal #15)

= $___________/hr

(17) Potential Annual Reduction = $________/hr (#16) X_______annual hours

of pumping = $____________.

RECOMMENDATIONS:

PUMPING PLANT EVALUATION
ELECTRIC MOTOR

Landowner EXAMPLE Date ______

SWCD ______ Field Office ______

Field No. ______ Well No. ______

Technician ______

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

Electricity Consumption:

(1) $\frac{(3.6)\ (28.8\ \text{Kh Factor})\ (10\ \text{Revolutions})\ (1\ \text{Multiplier})}{17.1\ \text{Time in Seconds}} = 60.6$ 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 2.31 ------------------- 97 ft.

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

(6) Output Horsepower = $\frac{237\ \text{TDH(\#5)} \times 840\ \text{GPM(\#2)}}{3960}$ = 50.3 H.P. out

11.5 (1.34) 15.41

(7) Input Horsepower = 60.6 KWH/hr(#1) (1.34 HP/KW) = 81.2 H.P. in.

(8) Overall Efficiency (O.E.) = $\frac{50.3\ \text{H.P. out(\#6)}\ (100)}{81.2\ \text{H.P. in(\#7)}}$ = 62 %

(9) Pump Efficiency = $\frac{62\ \text{O.E. \#8)}\ (100)}{\text{Motor Eff. 1/ } 90}$ = 68.9 %

1/ Standard Electric Motor Efficiencies

Submersible	Vertical Hollow Shaft	V-Belt Drive (motor Only)
3-phase motors - 80%	10 - 100 H.P. - 90%	10 - 40 H.P. - 88%
Single phase motors-75%	100 - 150 H.P. - 91%	40 -125 H.P. - 89%
	150 - 300 H.P. - 92%	125 -130 H.P. - 92%

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

(10) St.O.E. = (0.75) (.90 motor eff. as a decimal) (100) = 67.5 %

(11) Percent of Standard Efficiency = 62 O.E.(#8) x 100 / 67.5 St.O.E. (#10) = 91.9 %

Costs for Irrigation:

(12) Acre-Inches/hr pumped = 840 GPM(#2) / 450 = 1.87 Acre-Inch/hr

(13) Energy Cost/hr = 60.6 KWH/hr(#1) X $.08 Cost/KWH = $ 4.85 /hr.

(14) Energy Cost/Ac-In. = 4.85 Cost/hr(#13) / 1.87 Ac-In/hr(#12) = $ 2.59 /Ac-In.

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

(16) Est. Annual Energy Cost = $4.85 Cost/hr(#13) X 2500 Annual hrs. pumped = $ /yr. $12,125

2/ Inches Applied/Irrigation:

Furrows = (GPM #2) (hrs/set) (1161.6) / (ft/run) (In/row) (No. rows) = ____ In. applied

Sprinkler = (GPM #2) (hrs/Revolution) / (450) (Ac. Irrigated) = ____ In. applied

Potential Cost Reduction:

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

(18) Potential Energy Cost Reduction/hr =

4.85 Cost/hr(#13) x .081 Potential Reduction (#17 as decimal) = $ .39/hr.

(19) Potential Annual Reduction =

.39 Cost Reduction/hr(#18) X 2500 Annual hrs. pumped = $ 975 /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. Used) (60 min/hr) (1 meter constant) / 10 Time (min. to use Cu.Ft.)

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

(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 = 400 TDH (#5) x 800 GPM (#2) / 3960 = 80.8 Hp out

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

(8) Overall Efficiency (O.E.) = 80.8 H.P. out / 671.6 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 = 12 O.E. (#8) X 100 / 17 = 71 %

Costs for Irrigation

(10) Fuel Cost/hr = 1.71 MCF/hr (#1) X $3.20 Fuel Cost/MCF = $ 5.47 /hr

(11) Acre Inches per Hour = 800 GPM (#2) / 450 = 1.78 Ac-In/hr

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

= \$ 16410 / yr

1/ Inches/Irrigation Applied:

Furrows = $\frac{\text{\_\_ GPM (\#2) X \_\_ hrs/set X 1161.6}}{\text{\_\_ Ft/run X \_\_ In/row X \_\_ No. rows}}$ = ______ inches

Sprinkler = $\frac{\text{\_\_ GPM (\#2) X \_\_ hrs/revolution}}{\text{450 X \_\_ acres irrigated}}$ = ______ inches

Potential Cost Reduction

(15) Potential fuel reduction = 100% - 71 % Standard (#9) = 29 %

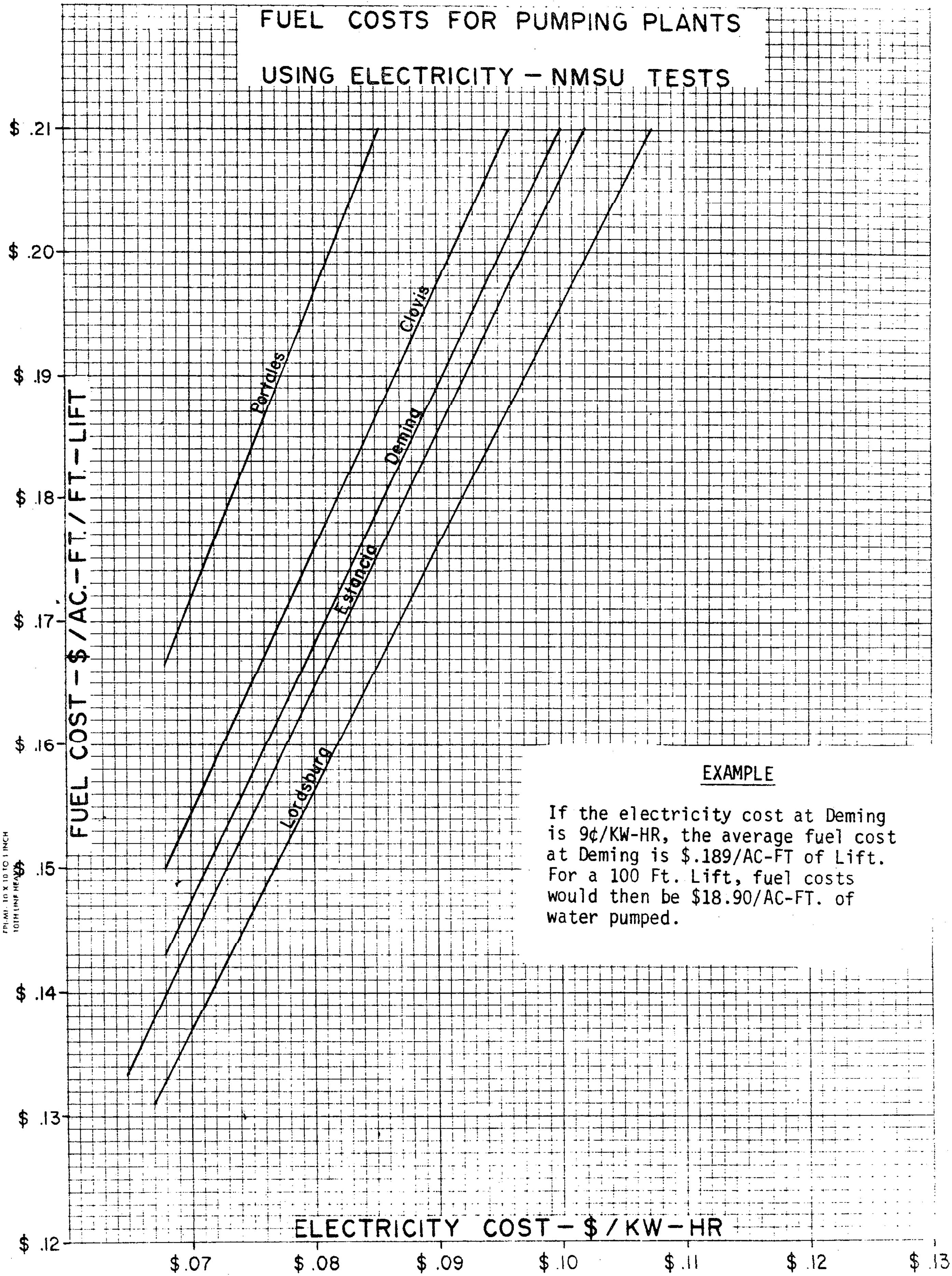
(16) Potential fuel cost reduction/hr = \$5.47 hr (#10) X .29 % (decimal #15)

= \$ 1.59 /hr

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

of pumping = \$ 4770 .

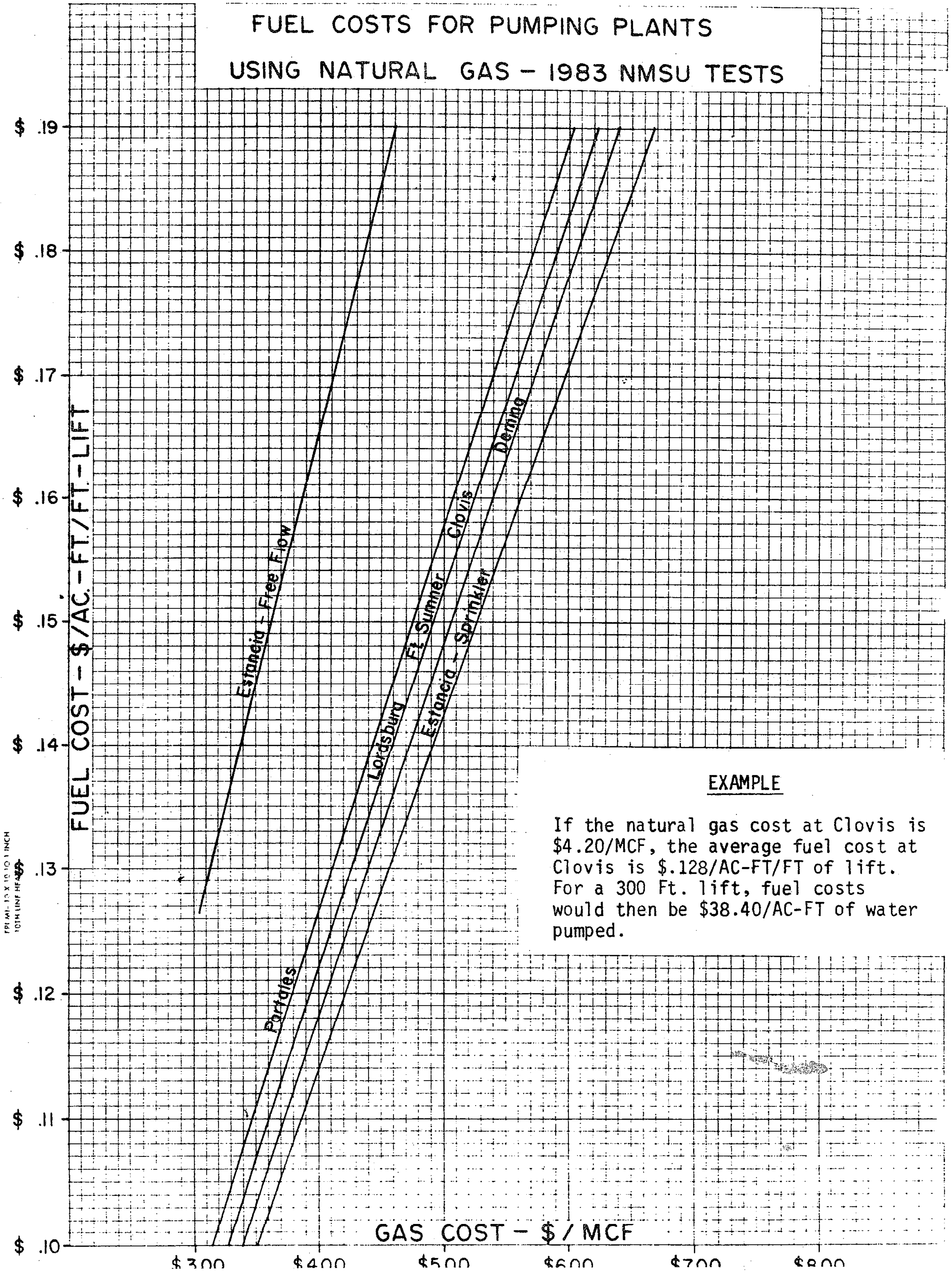
RECOMMENDATIONS:



EXAMPLE

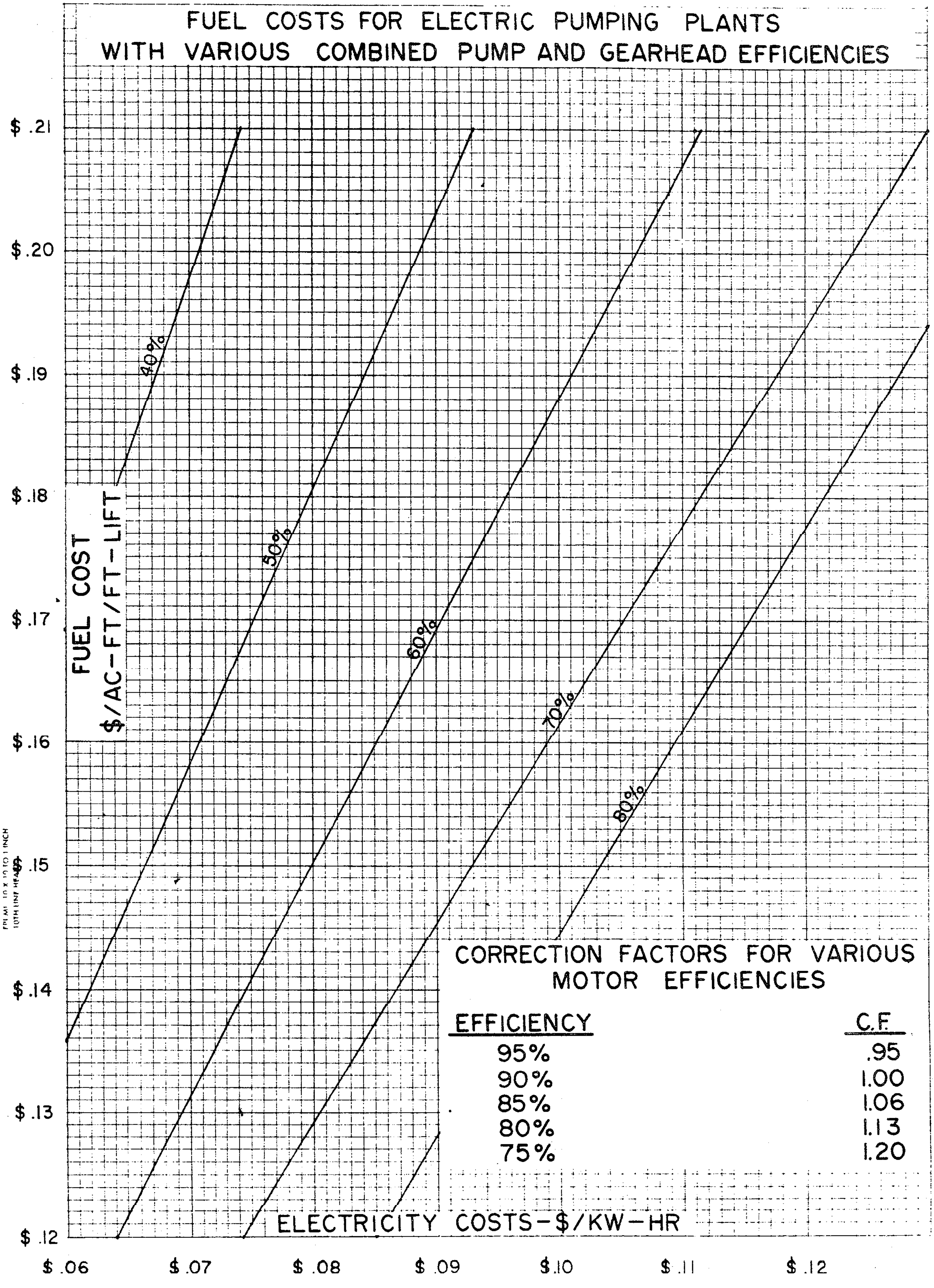
If the electricity cost at Deming is 9¢/KW-HR, the average fuel cost at Deming is $.189/AC-FT of Lift. For a 100 Ft. Lift, fuel costs would then be $18.90/AC-FT. of water pumped.

Sept. 1984



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.



CORRECTION FACTORS FOR VARIOUS MOTOR EFFICIENCIES

EFFICIENCY	C.F.
95%	.95
90%	1.00
85%	1.06
80%	1.13
75%	1.20

EXAMPLE

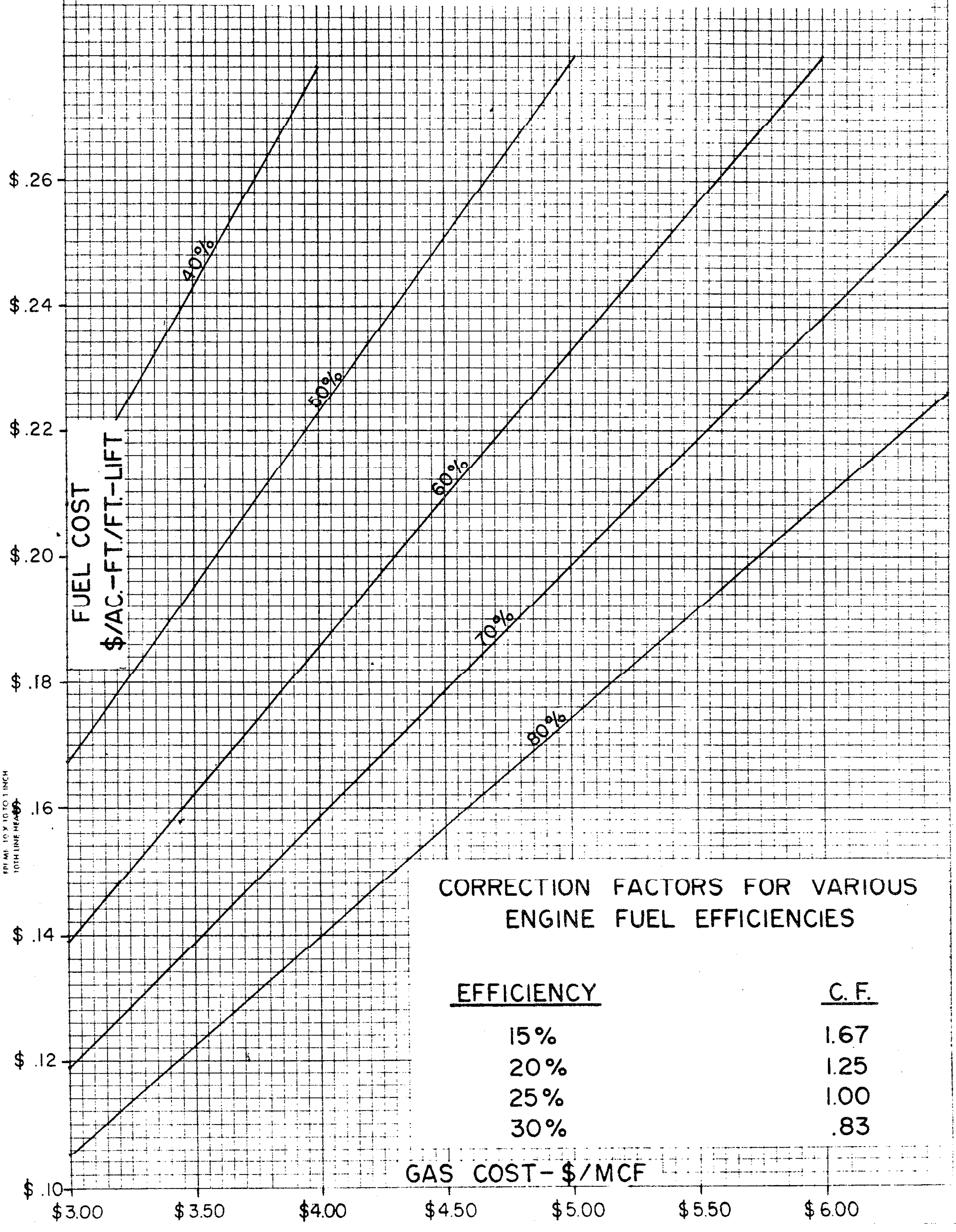
GIVEN:

An electric pumping plant is operating with a motor efficiency of 90% and a pump efficiency of 60%. The cost of electricity is $.10/KW-HR.

FIND: Fuel Cost/AC-FT/FT-Lift.

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

EFFICIENCY	C. F.
15%	1.67
20%	1.25
25%	1.00
30%	.83

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.

FIND: Fuel Cost/AC-FT/FT-Lift.

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

MFG	TYPE	CID	ENGINE RPM AND GEAR HEAD RATIO				
			1760 1:1	2112 6:5	2200 5:4	2346 4:3	2640 3:2
IH	V8	392	79	94	98	105	118
IH	V8	446	89	107	112	119	134
IH	V8	549	110	132	138	147	158
IH	V8	605	128	150	160	170	194
AMC	6	258	48	58	61	65	70
AMC	V8	360	68	88	91	95	105
FORD	V8	460	80	103	106	112	122
FORD	V8	534	96	113	118	126	-
CHRY	4	105	19	22	23	25	28
CHRY	V8	318	56	67	70	74.4	83.9
CHRY	V8	413	73	87	91	97	109
CHRY	V8	413TWIN	134	156	164	174	-
CHRY	V8	440	79	93	97	105	116
CHEV	4	153	29	33	35	38	42
CHEV	6	292	53	61	64	69	77
CHEV	V8	305	71	86	90	96	107
CHEV	V8	454	82	96	100	107	120
OLDS	V8	455	82	96	100	107	120
GMC	-	478	81	100	105	110	124
GMC	V-12	702	119	147	154	161	185
GMC	V-12	637	115	134	140	149	168

For engines not on this chart: Continuous duty HP, at 1760 rpm, corrected to 4000 feet elevation = CID x .2

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

OUTPUT HORSEPOWER

FOR VARIOUS INDUSTRIAL-TYPE ENGINES

Corrected For Continuous Duty
And 4000' Elevation

MFG	MODEL	FUEL	TYPE	CID	ENGINE RPM 1760	2112	2200	2346	2640
Minn.-Moline	HD220-4A	Gas	4 CYL	220	49	--	--	--	--
Minn.-Moline	DHD236-4A	Diesel	4 CYL	236	48	--	--	--	--
Minn.-Moline	HD425-6A	Gas	6 CYL	425	91	--	--	--	--
Minn.-Moline	DHD504-6A	Diesel	6 CYL	504	104	--	--	--	--
Minn.-Moline	HD504-6A	Gas	6 CYL	504	102	--	--	--	--
Minn.-Moline	DHD585-6A	Diesel	6 CYL	585	106	124	128	--	--
Minn.-Moline	HD605-6A	Gas	6 CYL	605	128	--	--	--	--
Minn.-Moline	HD800-A-6A	Gas	6 CYL	800	172	--	--	--	
IH	179	Diesel	3 CYL	179	35	39	41	42	48
IH	IR239	Diesel	4 CYL	239	50	52	54	56	59
IH	IR239-DT-Tur.	Diesel	4 CYL	239	61	65	67	68	70
IH	IR358	Diesel	6 CYL	358	68	79	81	85	88
IH	IR358-DT-Tur.	Diesel	6 CYL	358	94	100	101	105	107
IH	550	Diesel	8 CYL	550	123	130	--	--	--
IH	DT466-Turbo	Diesel	6 CYL	466	158	167	--	--	--
CHRY. MITSI.	441	Diesel	4 CYL	--	35	39	41	45	49
CHRY. MITSI.	641	Diesel	6 CYL	--	52	58	63	66	71
CHRY. MITSI.	655	Diesel	6 CYL	--	70	77	83	86	90

OUTPUT HORSEPOWER

FOR VARIOUS INDUSTRIAL-TYPE ENGINES

Corrected For Continuous Duty
And 4000' Elevation

MFG	MODEL	FUEL	TYPE	CID	ENGINE RPM				
					1760	2112	2200	2346	2640
JD	4219D	Diesel	4CYL N	219	43	48	51	53	--
JD	4276D	Diesel	4CYL N	276	58	56	57	58	--
JD	6392D	Diesel	6CYL N	392	62	70	73	--	--
JD	6404D	Diesel	6CYL N	404	70	76	78	--	--
JD	6414D	Diesel	6CYL N	414	80	88	90	--	--
JD	6414T	Diesel	6CYL T	414	99	104	105	--	--
JD	6466A	Diesel	6CYL T	466	159	167	--	--	--
JD	6619A	Diesel	6CYL T	619	194	200	--	--	--
CONT.	ZD144	Diesel	4 CYL	144	22	--	--	--	--
CONT.	GD157	Diesel	4 CYL	157	22	--	--	--	--
CONT.	GD174	Diesel	4 CYL	174	24	--	--	--	--
CONT.	GD193	Diesel	4 CYL	193	30	34	34	--	--
CONT.	ED201	Diesel	4 CYL	201	27	--	--	--	--
CONT.	ED208	Diesel	4 CYL	208	31	36	38	--	--
CONT.	ED223	Diesel	4 CYL	223	34	39	40	--	--
T.	HD243	Diesel	4 CYL	243	35	40	41	--	--
NT.	HD260	Diesel	4 CYL	260	38	43	44	45	--
CONT.	HD277	Diesel	4 CYL	277	41	46	47	48	--
CONT.	JD382	Diesel	4 CYL	382	51	--	--	--	--
CONT.	JD403	Diesel	4 CYL	403	54	--	--	--	--
CONT.	KD363	Diesel	6 CYL	363	58	67	70	72	76
CONT.	TD427	Diesel	6 CYL	427	68	79	81	--	--
CONT.	RD572	Diesel	6 CYL	572	85	--	--	--	--
CONT.	VD603	Diesel	8 CYL	603	94	109	112	116	120
CONT.	SD802	Diesel	6 CYL	802	127	--	--	--	--
AC	213	Diesel	2 CYL	80	16	19	21	21	24
AC	320	Diesel	3 CYL	121	24	30	31	33	37
AC	426	Diesel	4 CYL	159	34	43	44	45	51
AC	433T	Diesel	4 CYL	200	57	66	67	--	--
AC	433I	Diesel	4 CYL	200	63	72	74	--	--
AC	649T	Diesel	6 CYL	301	82	97	98	99	--
AC	649I	Diesel	6 CYL	301	100	116	119	120	--
AC	670T	Diesel	6 CYL	426	120	136	138	--	--
AC	670I	Diesel	6 CYL	426	134	155	158	--	--
AC	685T	Diesel	6 CYL	516	157	--	--	--	--
AC	685I	Diesel	6 CYL	516	203	--	--	--	--
AC	6138LT	Diesel	6 CYL	844	233	--	--	--	--
AC	6138T	Diesel	6 CYL	844	273	--	--	--	--
AC	6138I	Diesel	6 CYL	844	313	--	--	--	--

NOTE: I = Turbocharged - Intercooled
T - Turbocharged

OUTPUT HORSEPOWER

FOR VARIOUS INDUSTRIAL-TYPE ENGINES

Corrected For Continuous Duty
And 4000' Elevation

MFG	MODEL	FUEL	TYPE	CID	ENGINE RPM				
					1760	2112	2200	2346	2640
WAUK.	VRD310	Diesel	6	310	65	77	--	--	--
WAUK.	VRD283	Diesel	6	283	50	59	--	--	--
WAUK.	VRD232	Diesel	6	232	44	51	--	--	--
WAUK.	VRD155	Diesel	4	155	25	32	--	--	--
WAUK.	F476D	Diesel	6	475	--	126	--	--	--
WAUK.	F674D	Diesel	6	673	--	176	--	--	--
WAUK.	VRG310U	Nat.Gas	6	310	57	66	--	--	--
WAUK.	VRG283U	Nat.Gas	6	283	51	61	--	--	--
WAUK.	VRG265U	Nat.Gas	6	265	45	52	--	--	--
WAUK.	VRG232U	Nat.Gas	6	232	35	40	--	--	--
WAUK.	VRG155U	Nat.Gas	4	155	23	25	--	--	--
CAT	3208	Diesel	V-8	636	--	--	--	115	--
CAT	3304	Diesel	4	425	--	78	--	--	--
CAT	306	Diesel	6	638	115	--	--	--	--
CAT	3306L	Nat.Gas	6	638	115	--	--	--	--
CAT	3306H	Nat.Gas	6	638	133	--	--	--	
CAT	G342L	Nat.Gas	6	1246	1200 RPM 184	--	--	--	
CAT	G342H	Nat.Gas	6	1246	1200 RPM 207	--	--	--	--
CUMMINS	J401P	Diesel	6CYL N	401	71	77	79	--	--
CUMMINS	C464P	Diesel	6CYL N	464	89	103	107	--	--
CUMMINS	CT464P	Diesel	6CYL T	464	90	105	109	--	--
CUMMINS	CS464P	Diesel	6CYL S	464	97	109	112	--	--
CUMMINS	N495P	Diesel	4CYL N	495	88	--	--	--	--
CUMMINS	H672P	Diesel	6CYL N	672	115	--	--	--	--
CUMMINS	H743P	Diesel	6CYL N	743	142	--	--	--	--
CUMMINS	NS743P	Diesel	6CYL S	743	174	--	--	--	--
CUMMINS	N855P	Diesel	6CYL N	855	162	--	--	--	--
CUMMINS	NT855P	Diesel	6CYL T	855	189	--	--	--	--
CUMMINS	V352P	Diesel	6CYL N	352	63	76	78	82	90
CUMMINS	NTA370	Diesel	6CYL T	855	300	331	--	--	--
CUMMINS	GNH250IP	Nat.Gas	6CYL N	855	183	--	--	--	--
CUMMINS	GNH220IP	Nat.Gas	6CYL N	743	158	--	--	--	--
CUMMINS	GNHC41P	Nat.Gas	4CYL N	495	106	--	--	--	--

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 elctric meter was revolving at a rate of 10 revolutions in 17.1 seconds. The Kh 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. $$\text{WHP} = \frac{(\text{TDH})(\text{GPM})}{3960}$$

   $$= \frac{(237)(840)}{3960}$$

   $$= 50.3 \text{ HP}$$

3. $$\text{Fuel consumption} = \frac{(3.6)(\text{kh})(\text{R})}{t}$$

   $$= \frac{(3.6)(28.8)(10)}{17.1}$$

   = 60.6 Kw per hour

4. Input HP = (KWH/Hr)(HP/KW) = 60.6 x 1.34 = 81.2 HP

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

6. Cost per acre inch:

   a. Fuel cost per hour = (60.6Kw)(8¢ per Kw) = $4.85

   b. $$\text{Acre inches pumped} = \frac{840 \text{ gpm}}{450 \text{ gpm}} = 1.87 \text{ acre inch per hour}$$

   c. $$\text{Cost per acre inch} = \frac{\text{Cost per hour}}{\text{Acre inches pumped per hour}} = \frac{\$4.85}{1.87}$$

   = $2.59 per acre inch

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. $WHP = \frac{(TDH)(GPM)}{3960} = \frac{(400)(800)}{3960} = 80.8$ HP

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

   = 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. $\text{Overall efficiency (O.E.)} = \frac{WHP}{HP\ input} = \frac{(80.8\ HP)(100)}{671.6} = 12\%$

6. Determine percent of standard efficiency by comparing overall efficiency with standard efficiency of 17%.

   $\text{Percent of Standard Effiency} = \frac{(O.E)(100)}{17} = \frac{12 \times 100}{17} = 71\%$

7. Cost per acre inch:
   a. Fuel cost per hour = (1.71 MCF used)($3.20 per MCF) = $5.47/hr

   b. $\text{Acre inches applied} = \frac{800 \text{ gpm}}{450 \text{ gpm per cfs}} = 1.78$ acre-in per hour

   c. $\text{Cost per acre inch} = \frac{\text{fuel cost per hour}}{\text{Ac. in. applied}} = \frac{\$5.47}{1.78} = \$3.07$ per acre inch

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. TDH = (213)+(92.4) = 305.4 ft

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

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

   HP input of pump $= \frac{(WHP)}{\text{Pump eff.}} = \frac{(88.7)}{0.75} = 118.3$ 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. lift = (133')+(5') = 138 feet

   b. discharge pressure = (2.31)(60 psi) = 138.6 feet

   c. TDH = lift + discharge pressure
      = (138')+(138.6') = 276.6 feet

2. Find WHP:

$$WHP = \frac{(276.6\ ft)(800\ gpm)}{3960} = 55.9\ HP$$

3. Find necessary output horsepower of internal combustion engine:

Turbine pump efficiency = 75%
Rt. angle gear head efficiency = 95%
Output HP of Engine

$$= \frac{WHP}{Pump\ Eff.\ x\ Drive\ Eff.}$$

$$= \frac{55.9}{.75\ x\ .95}$$

$$= 78.4\ HP$$

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

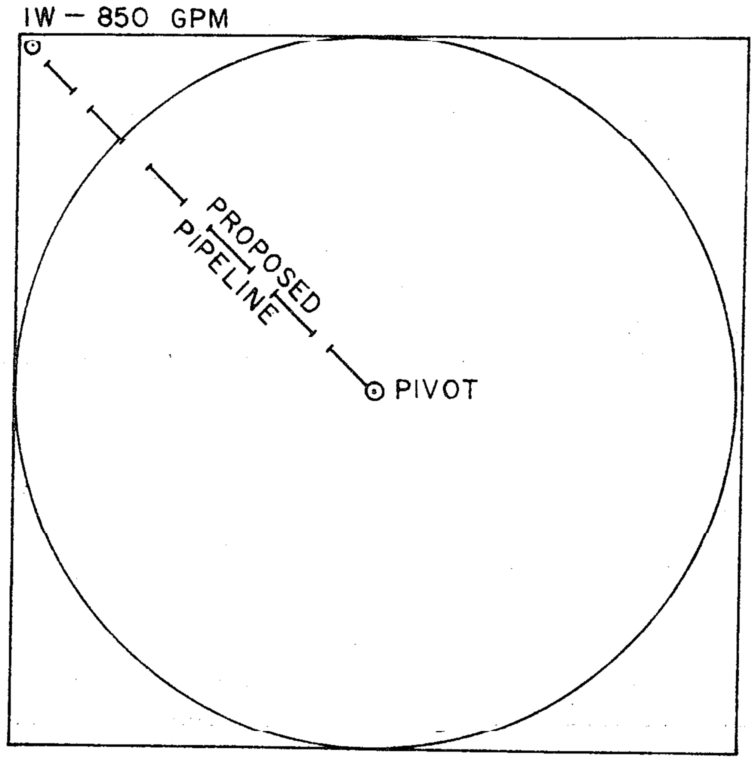
Type of Irrigation System: Circular sprinkler (65 percent efficiency)

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%.

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 $\frac{4.8 \times .5}{.65} = 3.7$ 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