Texas Agricultural Extension Service

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Pumping Plant Efficiency and Irrigation Costs

L. Leon New*

Inefficient pumps and power units are major contributors to excessively high irrigation costs. To minimize fuel consumption and pumping cost, pumping equipment must be carefully selected, properly maintained and replaced when necessary to maintain high efficiency. Efficient pumping plants with their lower pumping cost combined with efficient application of carefully timed irrigations can make the difference between profit and loss in irrigated crop production.

Factors which affect the amount of fuel required to pump a given quantity of water (a gallon, an acre-inch, an acre-foot, etc.) are: (1) the pumping lift or vertical distance from the water surface to the point of discharge, (2) the pressure required at the pump discharge to operate the irrigation system and (3) the efficiency of each component (power unit, pump drive or gear head and pump) of the pumping plant. Fuel requirements are lower when pumping lift is lower, discharge pressure is lower and pumping unit efficiency is higher. Pumping unit components in good condition and carefully selected to match requirements of a specific pumping situation can operate at efficiencies as high as those shown in Table 1. However, many pumping units on farms operate at efficiencies far below those shown.

Table 1. Irrigation pumping equipment efficiency.

Equipment	Attainable efficiency percent
Pumps (centrifugal, turbine)	75-82
Right angle pump drive (gear head)	95
Automotive-type engines	20-26
Industrial engines	
Diesel	25-37
Natural gas	24-27
Electric motors	
Small	75-85
Large	85-92

Reasons for low efficiency include wear, improper adjustment or failure to select equipment to match the specific pumping conditions. An engine operating at 8 percent efficiency will use three times as much fuel to do the same amount of work (pump the same amount of water at the same total head) as one operating at 24 percent efficiency. A pump that is 25 percent efficient requires three times as much power (fuel) to do the same amount of work as a pump that is 75 percent efficient. From the standpoint of pumping cost, a very serious condition exists when both the engine and the pump operate at low efficiency. For example, if the engine operates at 8 percent efficiency and the pump at 25 percent efficiency, the pumping plant would use nine times as much fuel to pump the same amount of water as one with an engine efficiency of 24 percent and a pump efficiency of 75 percent.

*Extension agricultural engineer—irrigation, The Texas A&M University System.

Pumping Plant Components

An irrigation pumping plant has three major components: a power unit, a pump drive or gear head and a pump. The pump lineshaft and the motor shaft of electric-powered pumping plants are usually direct-connected which makes a pump drive or gear head unnecessary.

Pump. A pump properly selected to match specific conditions of pumping rate, pumping lift and discharge pressure can operate at 80 percent efficiency, or more. However, many pumps operate at much lower efficiency because of failure to select the pump to match pumping conditions, changes in pumping lift or discharge pressure, improper adjustment and wear. Pump wear occurs rapidly and efficiency declines when the water contains sand or other abrasives. The effect of pump efficiency on annual fuel cost is illustrated in Table 2.

Irrigation pumps should be selected to match specific well characteristics of well yield and pumping lift. Add any required discharge pressure (pounds per square inch converted to feet of head) to pumping lift to obtain total pumping head. If the water source is a lake, pond or stream, substitute desired pumping rate for well yield. Use pump manufacturer's performance ratings and the well pumping test results to obtain the best match for high pump efficiency. Pump performance ratings or curves are available from the dealer or manufacturer, Figure 1. The pump described would operate at 77 percent efficiency, or higher for any pumping situation between 600 gallons per minute with

Table 2. Influence of pump efficiency on annual fuel cost for pumping rate of 100 gallons per minute and 2,400 hours of annual operation. For other pumping rates, multiply costs in the table by the appropriate number. For example, for a pumping rate of 600 GPM, multiply costs by 6.

Fuel	Pump efficiency (percent)	Pumping Lift in Feet		
		100	200	300
Natural gas	75	$364	$728	$1,092
@$4.00 per Mcf	50	546	1,092	1,638
	25	1,092	2,184	3,276
Electricity	75	$549	$1,097	$1,646
@$0.08 per KWH	50	823	1,646	2,469
	25	1,646	3,292	4,938
Diesel	75	$555	$1,110	$1,664
@$1.00 per gallon	50	832	1,664	2,497
	25	1,664	3,329	4,993
Propane	75	$529	$1,057	$1,586
@$0.60 per gallon	50	793	1,586	2,379
	25	1,586	3,171	4,757

64 feet total pumping head and 800 GPM at 57 feet total head. Peak efficiency of 82 percent occurs when pumping 800 GPM at 57 feet total head. Performance information is available for every pump. Use it to achieve maximum efficiency.

A thorough pumping test on new wells to determine the optimum well yield and pumping lift is essential for accurate pump selection. Measurement of pumping rate and pumping lift on old wells at least once each year is a useful management tool. A record of these measurements will help identify and diagnose pump or well problems and provide a basis for selection of a replacement pump, if that becomes necessary. The measurements can be especially helpful in the event of sudden pump failure.

Power unit. Power unit efficiency is also important to pumping plant performance. Efficiency of electric motors up to 10 horsepower usually ranges between 75 and 85 percent. Motors of 100 horsepower or larger usually attain efficiencies of 90 to 92 percent while motors in the 15 to 75 horsepower range may have efficiencies of 85 to 90 percent. Regular maintenance to ensure proper bearing lubrication and unobstructed air passages will maintain high motor efficiency.

Efficiency of internal combustion engines is inherently low. The top efficiency for automotive engines is 23 to 26 percent. Heavy industrial engines may achieve efficiencies of 24 to 37 percent while light industrial engines have efficiencies of 25 to 26 percent. Achievement of these efficiencies is possible only with engines in excellent condition, properly tuned, running at optimum speed and properly loaded. Primary reasons for lower efficiency and higher fuel consumption are: wear, improper tuning and partial loading.

Partial loading may be difficult to overcome, especially in situations requiring relatively small engines. Since every percentage point improvement in engine performance means reduced fuel consumption, checking engine suppliers and shops for the best engine for a specific job can pay good dividends. Some shops offer engine modifications that improve performance. Modifications have improved automotive engine efficiency 3 to 5 percent in some cases.

Each percentage increase in engine efficiency reduces fuel consumption about 5 percent. An engine that operates at 19 percent efficiency will use 26 percent more fuel doing the same work than one operating at 24 percent efficiency. Figure 2 illustrates the relationship between engine efficiency and fuel consumption using 24 percent as the "standard" basis for comparision.

Pump drive. The pump drive transmits power from the power unit to the pump. The lineshaft of electric-driven pumps is normally connected directly to the

Figure 1. Typical pump performance curves. Curves describe performance for one stage of a vertical turbine pump. Stages would be added as necessary to obtain required total head.

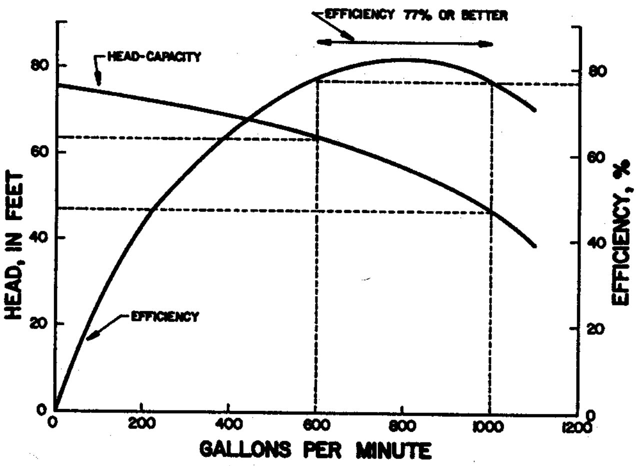
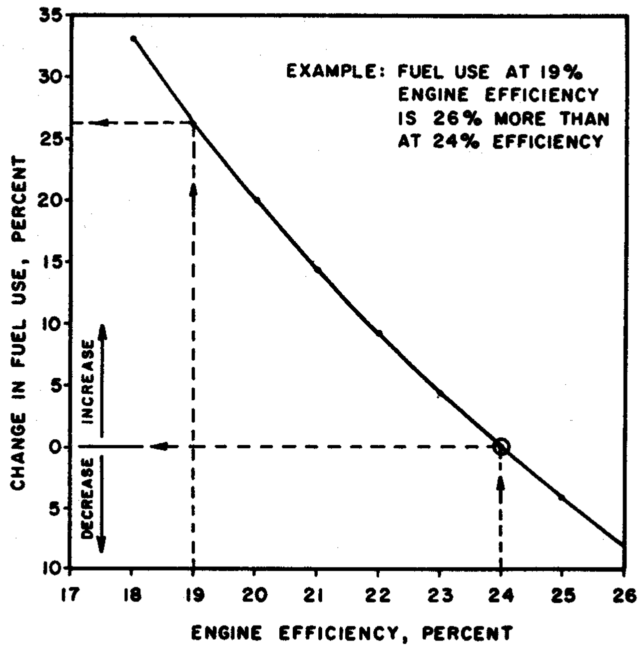


Figure 2. Influence of engine efficiency on fuel consumption. Based on 24 percent as "standard" engine efficiency.



motor shaft, eliminating the necessity for a pump drive. When the pump is driven by an internal combustion engine, the pump drive changes the horizontal direction of the engine shaft to the vertical direction of the pump lineshaft (for well pumps). The most common pump drive is a right-angle gear drive, or "gear head." It must be selected in the correct horsepower size and with an appropriate gear ratio to allow the engine and the pump to operate at optimum speeds. Efficiency of right-angle gear drives is about 95 percent. Belt drives may vary in efficiency from about 85 to 95 percent. Efficiency of combined belt and gear head drives is about 80 percent.

Field Measurements to Determine Efficiency

Determination of overall pumping plant efficiency requires measurement of pumping rate, pumping lift, fuel use and discharge pressure, if any. Assuming that fuel use rate is determined from the installed utility meter or by measuring liquid fuel in the fuel tank, the only special equipment needed is an electric well sounder or an air line in the well to measure pumping lift, a flow meter to measure pumping rate and pressure gauge in the pump discharge pipe to measure discharge pressure (not necessary on open discharge).

The procedure for determining overall pumping plant performance and comparing it to a standard for irrigation pumping plants is described in Texas Agricultural Extension Service publication L-1718, "Evaluating Irrigation Pumping Plant Performance."

Unfortunately, determination of overall pumping plant performance only shows whether overall performance is good or bad, it does not identify pump and power unit efficiency separately. Efficiency of electric motors can be reasonably assumed and pump efficiency calculated, but pumping plants with internal combustion engines require a more comprehensive testing procedure to determine both engine and pump efficiency.

In addition to the measurements listed above, a complete pumping plant efficiency test requires measurement of the actual power output of the engine when the power unit is an internal combustion engine. The drive shaft between the engine and gear head is replaced temporarily with a special drive shaft including a torque cell to measure engine power output. Efficiency of the engine and the pump can then be determined during the test. If the efficiency of either unit is very low, the test provides the basis for a decision about major repair or replacement.

Measurements to determine overall pumping plant efficiency can be made by most producers. Determining overall pumping plant efficiency each year and maintaining a record of the measurements is a management practice that can pay excellent dividends. If overall efficiency is found to be low, assistance of a pump company, consulting firm, service agency or organization can be obtained to perform a complete pumping plant evaluation to identify the problem.

Demonstration Program Results and Recommendations

More than 500 pumping plant efficiency tests have been performed in a Texas Agricultural Extension Service demonstration program conducted since 1975. Pump efficiencies range from less than 20 percent to more than 80 percent with an average of 55 percent. The average overall natural gas-powered pumping plant efficiency is 11.6 percent with an average natural gas engine efficiency of 20 percent. For comparison, the standard for natural gas-powered deep-well turbine pumping plants is 75 percent pump efficiency, 24 percent engine efficiency and 17 percent overall efficiency. The demonstration tests show that average fuel use is 32 percent more than required by a pumping plant operating at the performance standard. A summary of pumping plant performance data from the Extension efficiency testing demonstrations is shown in Table 3.

Table 3. Average power unit and pump efficiencies, fuel consumption, and specific fuel cost for natural gas, electric and diesel pumping plants. Extension pumping plant efficiency demonstration tests, 1975-85.

	Natural Gas	Electricity		Diesel
		VHS	Submersible	
1. Number of tests	455	91	38	35
2. Power unit				
a. Horsepower, HP	87	81	20	108
b. Fuel per HP, *	12.3	—	—	.062
c. Efficiency, %	20	90	79	30
3. Pump				
a. Flow rate, GPM	574	594	136	688
b. Pumping lift, ft.	300	267	248	289
c. Discharge head, psi	14	20	12	40
d. Efficiency, %	58	58	51	66
4. Overall efficiency, %	11.6	52	40.0	19.3
5. Specific fuel consumption */acre-inch/100 ft. head	272	17.3	22.9	1.16
6. Fuel cost@*				
a. $ Per acre-inch	3.45	4.28	4.98	4.15
b. Specific water cost, $/acre-inch/100 ft. head	1.08	1.45	1.83	1.10

*Natural gas-cubic feet @ $4.00 MCF
Electricity-KWH @ $.08 KWH
Diesel-gallon @ $.95 gallon

There is no exact efficiency at which major repair costs are automatically justified. Factors which influence the monetary effect of low pumping unit efficiency are pumping rate, pumping lift, fuel price and the number of hours the pumping unit is operated each year. Projected savings, considering the combined influence of all these factors compared with the cost of pumping unit repairs, are the best basis for a decision about repairs.

Repair costs can often be recovered in 1 to 2 years when pumping level is 300 feet or more, pumping rate is 600 gallons per minute or more and pump efficiency is less than 50 percent. Five to 6 years may be required to recover pump repair costs when pump efficiency is 60 percent, or more. Higher fuel prices, increased pumping head and more annual operating time shorten the period required to recover major repair costs, even when pump efficiency is 60 percent, or higher.

The efficiency of engines in poor mechanical condition or improperly tuned or adjusted may be very low. For example, fuel use does not change if one or more cylinders misfire but power output decreases drastically. Lower engine efficiency caused by partial loading alone does not justify engine replacement. Consider rotation of engines to other wells to improve loading. Choose a smaller engine when normal replacement is needed.

Use of alternative fuels is often considered as a means of reducing pumping cost. The cost of the amount of each fuel needed to produce the same amount of work must be considered. The performance standard for irrigation pumping plants provides a basis for comparing the amount of fuel needed if all components of the pumping unit perform at the standard level.

On this basis, the following quantities of fuel would be needed to do the same work as 1 MCF of natural gas: 6.1 gallons of diesel, 9.7 gallons of propane or 75.4 KWH electricity. Use fuel bills to identify current fuel use. Determine the quantity of an alternative fuel needed and apply the appropriate price. However, to determine whether changing to a different fuel would be advisable, all costs of owning (depreciation and interest on investment) and operating (fuel, lubrication, maintenance and repair) the power unit must be considered.

High pumping efficiency is likely to be even more important in the future. Although energy prices may moderate at times, the long term trend for increased price is not likely to change. Identification of pumping rate, pumping lift and fuel use per hour for individual wells or pumping plants is recommended. A record of these data determined regularly, perhaps annually, provides a basis for comparison of current and past performance and may prevent unwarranted repairs or allow timely scheduling of repairs to prevent costly down-time during the irrigation season.

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