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Loading Effects on Irrigation Power Unit Performance[1]

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INTRODUCTION

In Florida, irrigation pumps are typically powered with diesel engines or electric motors. Gasoline or LP gas engines are also sometimes used, although much less frequently. Each of these power units operates at its highest efficiency when fully loaded, that is, when loaded near its maximum continuous horsepower rating. The efficiency of an irrigation power unit is reduced if the power unit is either too large or too small for the pump it is powering.

OVERLOADING POWER UNITS

The consequences of overloading a power unit are severe: both inefficient operation and power unit damage may be expected to occur. An internal combustion engine should never be operated for long periods of time under a load that exceeds its continuous horsepower rating for the speed at which it is being operated. When an internal combustion engine is overloaded, it will waste fuel, wear rapidly and fail prematurely.

Many electric motors can safely be overloaded to a small degree, depending on the service factor stamped on the motor. However, this is usually limited to about 10 percent of the horsepower rating stamped on the motor. If the permitted overload for an electric motor is exceeded, it also will operate inefficiently, wear rapidly and fail prematurely.

UNDERLOADING POWER UNITS

If power units are underloaded, they will operate inefficiently, wasting fuel or electric power. A power unit that is larger than required also will cost more than one of the proper size.

The performance effects of underloading diesel, gasoline, LP gas and electric power units are shown in Figure 1 . This graph compares fuel use performance ratings with percentages of continuous horsepower rating at which a unit is loaded. The fuel use performance rating is the ratio of the power unit's performance under a given partial load to its performance when fully loaded, expressed as a percentage. Thus, the performance rating is less than 100 percent for a partially loaded power unit and ranges up to 100 percent for a fully loaded one. The use of performance ratings rather than efficiency measurements allows the effects of loading to be compared for the four different types of power units most often used for irrigation pumping.

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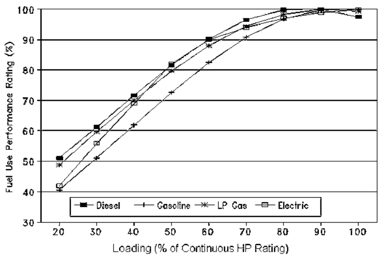

Figure 1. Fuel use peformance ratings of irrigation power units as a function of loading.

From Figure 1, it should be noted that the general relationship between performance rating and percentage of continuous horsepower rating is not linear. Instead, performance ratings are high when power units are nearly fully loaded; they decrease slowly for small underloads, then decrease more rapidly for severe underloads.

The following specific points should be noted in Figure 1 :

- All of the power units operate at high efficiency (above 95 percent) when loaded at more than 80 percent of their continuous horsepower rating.
- Diesel engines and electric motors generally have performance ratings above 90 percent if they are loaded at more than 60 percent.
- The performance of gasoline engines drops most rapidly, yet is still above 90 percent when the engines are loaded at 70 percent.
- Below 60 to 70 percent of their continuous horsepower rating, performance ratings of all power units drop 10 to 12 percent for each 10 percent drop in loading.

PERFORMANCE STANDARDS AND FUEL USE RATES

Table 1 lists the performance standards for the four types of power units shown in Figure 1. Performance standards are measured in units of horsepower-hours per gallon (hp-hr/gal) of fuel for internal combustion engines and horsepower-hours per kilowatt-hour (hp-hr/kwh) for electric motors. These standards rate the effectiveness of a typical power unit in converting fuel or electrical power to mechanical power. They are based on the assumption that the power unit is in good repair and fully loaded.

Table 1. Performance standards for fully loaded irrigation power units.

Type of Power Unit	Performance Standard	Fuel Use Rate
Diesel	14.75 hp-hr/gal	0.0678 gal/hp-hr
Gasoline	11.30 hp-hr/gal	0.0885 gal/hp-hr
LP gas (propane)	8.92 hp-hr/gal	0.112 gal/hp-hr
Electric	1.18 hp-hr/kwh	0.847 kwh/hp-hr

Table 1 also lists fuel use rates for the four previously discussed types of power units. The fuel use rate is the inverse of the performance standard. To estimate the fuel use rate for a specific power unit, multiply the power unit size (continuous horsepower rating) times the fuel use rate from Table 1 . The result is the fuel use rate in gallons (or kilowatts) per hour. This procedure is illustrated in the following examples.

Estimate the fuel use rate for a 100-hp diesel power unit that is fully loaded. Multiply 100 hp times 0.0678 gal/hp-hr (from Table 1) to obtain 6.78 gal/hr. This power unit would be expected to use 6.78 gallons of diesel fuel per hour of operation.

As another example, estimate the electric power use rate for a 100-hp electric motor that is fully loaded. Multiply 100 hp times 0.874 kwh/hp-hr to obtain 87.4 kwh/hr. This power unit would be expected to use 87.4 kwh of electric power per hour of operation.

ESTIMATING FUEL WASTE

Figure 1 demonstrates that even if a power unit is as much as 20 percent larger than required by an irrigation pump, the power unit will still operate efficiently because it is nearly fully loaded. However, if a power unit is greatly oversized, it will not be adequately loaded and will waste fuel during operation. Data from Figure 1 were used to construct Figure 2, which estimates fuel waste as a result of oversizing a power unit. The use of Figure 2 to estimate fuel waste is illustrated in the following examples.

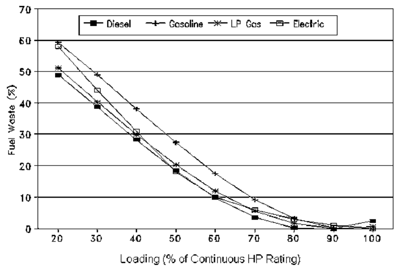

Figure 2. Percentage of fuel waste by irrigation power units as a funtion of loading.

If a 100-hp electric motor were installed where a 50-hp motor would be adequate (percentage of continuous rated hp = 50 percent), about 18 percent of the electricity used would be wasted (based on Figure 2). That is, a 50-hp electric motor would use 18 percent less energy than the 100-hp motor when each was driving a 50-hp load.

If a 100-hp electric motor were installed where a 75-hp motor was needed (percentage of continuous rating = 75 percent), only about 5 percent of the electricity used would be wasted (based on Figure 2). Thus, when there is relatively little underloading, energy waste is small.

As another example, if a gasoline engine were loaded at only 50 percent, it would be expected to waste about 27 percent of its fuel compared with a power unit of the proper size (based on Figure 2).

The last examples represent very extreme cases of power unit oversizing. If diesel or LP gas engines were loaded at only 20 percent of their continuous horsepower rating levels, about 50 percent of the fuel used would be wasted. In gasoline engines and electric motors, almost 60 percent of the fuel or energy used would be wasted. If a 100-hp power unit were used when only a 20-hp unit was needed, a 20 percent loading rate would occur.

SUMMARY

A power unit for an irrigation pump operates at its highest efficiency if it is fully loaded. When a power unit is overloaded, it will waste fuel, wear rapidly and fail prematurely. Oversizing (underloading) power units by up to 20 percent will result in little loss in performance or fuel waste. However, when power units are oversized by more than 30 to 40 percent, fuel waste will increase by 10 to 12 percent for every additional 10 percent reduction in loading.

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