

IRRIGATION POWER UNIT SELECTION

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I. GENERAL

Any device used to drive an irrigation pump is called an irrigation power unit. Irrigation power units commonly used include electric motors and internal combustion engines. Farm tractors are used occasionally.

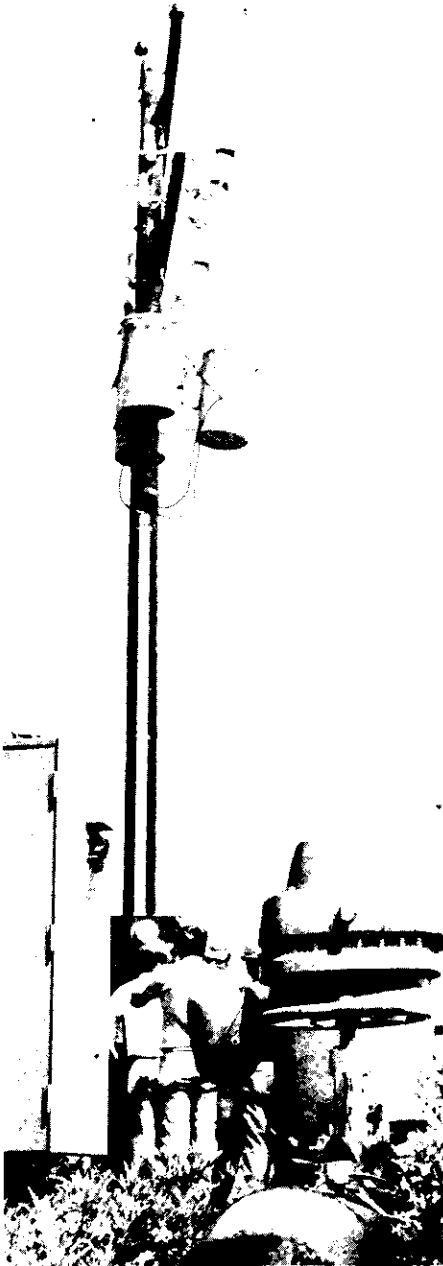
An irrigation power unit must fit the irrigation pump requirements to maintain an efficient operation. An engine or motor that is too small cannot provide the power necessary to deliver water at the rate and/or pressure required by the irrigation system. An engine or motor larger than necessary may provide service, but at an excessive initial cost.

The properly designed power unit will meet the requirements of an irrigation system without supporting idle capacity. An irrigation load is constant, so the power unit chosen must be suitable for continuous duty at the design load. Electric motors are designed and rated for constant loads. An internal combustion engine must either be rated for continuous duty at the design load or derated from some other horsepower rating to a continuous horsepower rating. Either industrial internal combustion engines or electric motors are suitable for irrigation. Farm tractors should not be used for permanent

installations because they are not designed for the 24-hour-per-day continuous loading required for irrigation. If a tractor is to be used on a temporary installation, it should be operated at less than maximum horsepower and be protected with safety switches to prevent engine damage.

The power unit selection should be made only after considering the following:

- A. The amount of brake horsepower for pumping. This includes the amount of water to be pumped, elevation differences between the source and the delivery point, the operating pressure of the system, friction losses, power unit efficiency, and pump efficiency.
- B. Hours of operation per season.
- C. Availability and cost of energy or fuel (in case of electricity, availability of three-phase power may influence the selection).
- D. Availability of parts and service.
- E. Depreciation.
- F. Portability of the unit if required.
- G. Labor requirements and convenience of operations.
- H. Initial cost.



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It is very important to match the engine horsepower to the requirements of the pump. Previously used power units should be carefully checked and evaluated as to condition, available horsepower, and speed. The use of an old, misfit power unit can be more costly from an operating standpoint than a more expensive unit properly fitted for the job.

II. POWER REQUIREMENTS

Determining the actual horsepower requirement of the power unit requires that the total dynamic head, the pumping rate, the efficiency of the pump, the drive efficiency, and the type of power unit be known.

To determine total operating or dynamic head, the head requirements for each part of the system must be combined. By definition, Total Dynamic Head = Total Static Head + Pressure Head + Friction Head + Velocity Head (Figure 1).

TOTAL STATIC HEAD is the total vertical distance the pump must lift the water. When pumping from a well, this would be the distance from the water level in the well, when the pump is delivering the desired gallonage, to ground level plus the distance the water is lifted from ground level to the discharge point.

PRESSURE HEAD. Sprinklers require pressure to operate. Center pivot systems require a certain pressure at the pivot point to distribute the water properly. Note:

The pressure in PSI is normally converted to feet of head for calculation purposes (see Table 1). $PSI \times 2.31 = \text{Head in Feet of Water}$.

FRICITION HEAD is the loss due to friction when water flows through pipes. Additional friction loss also occurs when water flows through fittings or valves, around corners, or at increases or decreases in pipe size. Values for these losses are obtained from friction loss tables.

VELOCITY HEAD is the energy required to initially get water into motion. This is a relatively small amount of energy and is usually negligible when computing losses in an irrigation system.

The useful work done by a pump is called "water horsepower" (WHP) and is calculated as follows:

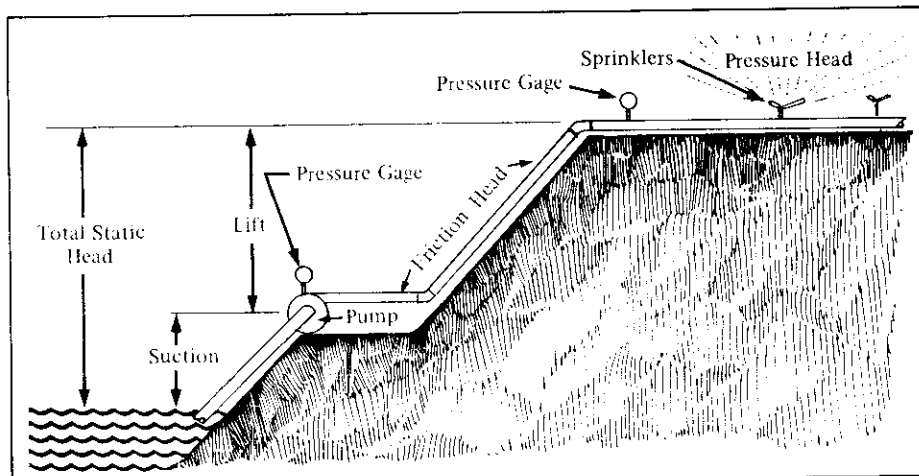


Figure 1. Total dynamic head is the sum of total static head plus friction head plus pressure head. Total dynamic head will equal gauge pressure reading at the pump x 2.31 plus the suction lift. Total dynamic head will also equal gauge pressure reading at the sprinklers x 2.31 plus total static head plus friction head.

$$WHP = \frac{Q \times TDH}{3960}$$

Q = Discharge in GPM (gallons per minute) TDH = Total dynamic head in feet

Some other formulas which may be used to determine WHP but use different units of measurement are:

$$WHP = \frac{Q \times TDH}{8.8}$$

WHP = Water Horsepower
Q = Discharge in CFS (cubic feet per second)

$$WHP = \frac{Q \times P}{1714}$$

WHP = Water Horsepower
Q = Discharge in GPM (gallons per minute)
P = Pressure in PSI (pounds per square inch)

Table 1. PSI (Pounds Per Square Inch) Versus Head in Feet of Water.

psi	Head (Ft)	psi	Head (Ft)	psi	Head (Ft)
0	0	35	80.8	70	162
5	11.5	40	92.4	75	173
10	23.1	45	104	80	185
15	34.6	50	115	85	196
20	46.2	55	127	90	208
25	57.7	60	138	95	219
30	69.3	65	150	100	231

The water horsepower represents the power required to operate the pump if the pump and drive were 100 percent efficient. The brake horsepower (BHP) is the actual horsepower requirement at the drive unit connection and takes pump and drive inefficiencies into consideration. The continuous horsepower rating of the power

unit must equal this value. Brake horsepower is calculated as follows:

$$\text{BHP} = \frac{\text{WHP}}{\text{Pump Efficiency} \times \text{Drive Efficiency}}$$

BHP = Brake Horsepower (continuous horsepower rating of power unit)

WHP = Water Horsepower

The pump efficiency must be obtained specifically for an individual pump from company information. The drive efficiency may be found in Table 2. A well designed irrigation pump should be 70 percent to 80 percent efficient. Strive for a higher efficiency at the required pumping rate and total dynamic head. A figure of 75 percent can normally be used for preliminary planning.

Table 2. Drive Efficiency.

Type of Drive	Normal Efficiency
Direct	100%
Flat-Belt (straight)	85%
Flat-Belt (1/4 to 1/2 turn)	75%
V-Belt	95%
Right Angle Gear Head	95%

III. INTERNAL COMBUSTION ENGINES

A. General

Internal combustion engines may use gasoline, diesel, propane or natural gas for fuel (Figure 2). Internal combustion engines are advantageous where portability and/or a variable speed power source is desired. Internal combustion engines must be used if an electric power source is not available. Disadvantages of internal combustion engines for irrigation service include the necessity of on-site fuel storage, higher service requirements and the need for



Figure 2. Portable diesel power unit connected to a deep well turbine pump through a right angle drive.

an electric generator if electricity is required to run the irrigation system.

B. Horsepower Ratings

Manufacturers have developed performance curves showing horsepower ratings at various

speeds for each of their internal combustion engines, for use as a basis in engine selection. These curves are developed in a laboratory under conditions of 60° F temperature, mean sea level elevation, and with a bare engine to produce the most horsepower per unit of engine weight. For field use, these curves must be corrected to reflect the power loss caused by the use of accessories, elevation differences, and air temperature. If an electrical generator or other auxiliary equipment is run, that load must be included in determining the total power required.

Some manufacturers publish both dynamometer and continuous brake horsepower curves in their literature. When only one curve is shown, that curve will generally be the horsepower determined by a

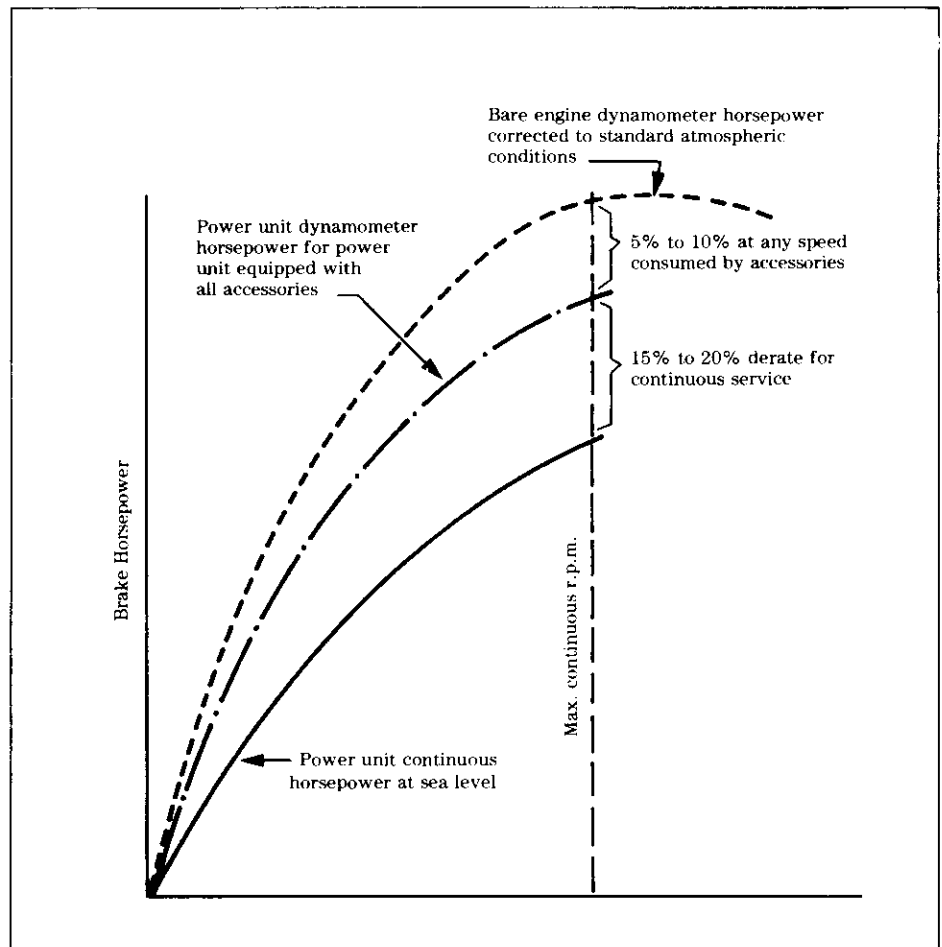


Figure 3. Horsepower vs. r.p.m. curve for internal combustion engines.

dynamometer under laboratory conditions. If continuous horsepower curves are not available for an internal combustion engine it is necessary to further correct the horsepower curve to compensate for the continuous loading required in irrigation pumping. Figure 3 shows how a horsepower versus RPM curve is changed after corrections are made for accessories and continuous operation. Actual reductions of bare engine horsepower are shown in Table 3.

Table 3. Corrections to Bare Engine Horsepower Developed under Laboratory Conditions.

For each 1,000 feet above sea level deduct	3%
For each 10° F above 60° F deduct	1%
For accessories (generator, etc.) deduct	5%
For radiator and fan deduct	5%
For continuous operation deduct	20%

The most efficient operating load for an internal combustion engine is at or slightly under the continuous brake horsepower curve. Running an engine under much lighter loads usually results in poorer fuel economy for the water delivered. However, engine life expectancy will be higher. Running over the maximum continuous rated horsepower invites engine trouble as well as excessive fuel consumption.

Gearheads on deepwell turbine pumps come in various ratios so the most efficient engine speed can be matched to the desired pump speed. Always check the desired pump speed before selecting the gearhead ratio.

C. Cooling Jackets

Heat exchangers should meet the size requirements based on engine size and established by the manufacturer.

In some instances, heat exchangers may be used on installations in sheltered areas where air movement around the unit is very

poor. Where the source of water is reasonably warm, the use of a larger than normal heat exchanger is recommended. Addition of a fan to move hot air away from the engine may increase fuel consumption slightly but will eliminate safety switch shutdowns during extremely hot weather.

IV. ELECTRIC MOTORS

A. General

Electric motors are used on many irrigation systems. If properly installed and protected, electric motors will provide many years of service. Advantages of electric power include relatively long motor life, low maintenance costs, dependability, and ease of control and operation. An electric motor will deliver full power throughout its life and can be operated from no load to full load without damage. Disadvantages of electric motors include constant speed, an electric power supply required at each pumping location, and normally an annual minimum power cost.

B. Motor Types

Most large electric motors used for irrigation are squirrel cage induction type, three-phase, 460-volt motors. Pumps may be connected to the motors by direct couplings, right angle drives, or belts. Most common, and best if practical, is a direct coupling. Right angle drives and belt drives are less than 100 percent efficient and require more energy.

Most electrical motors used on centrifugal pumps will be horizontal shaft (Figure 4). On deep well turbine pumps either a vertical hollow-shaft electric motor (Figure 5) or a horizontal shaft electric motor together with a hollow-shaft right angle drive must be used (Figure 6). The hollow-shaft unit is necessary so pump impellers can be adjusted.

Electric motor life is normally determined by the motor winding insulation life. Electric motor insulation is normally rated for a life of 20,000 hours. For example, Class A insulation has a 20,000-hour life at 105° C; Class B, a 20,000-hour life at 130° C; and Class F, a 20,000-life at 165° C. Electric motors for irrigation should be rated for continuous duty at 40° C or higher maximum ambient temperature and have Class B or better insulation.

Overloading an electric motor causes internal temperatures to rise and drastically shortens expected motor life. Therefore, proper motor sizing is very important. Never load an electric motor over its rated horsepower. If the calculated total pump load is close to the selected motor size, select a motor with a service factor of 1.15. Because irrigation pumps are usually located several miles from electrical substations there is usually some voltage imbalance

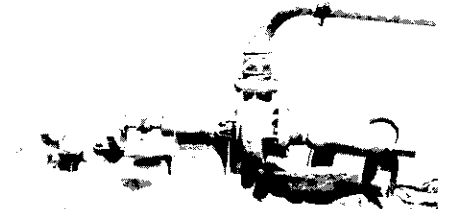


Figure 4. Electric horizontal shaft motor connected to a centrifugal pump.



Figure 5. Hollow-shaft electric motor connected to a deep well turbine pump.

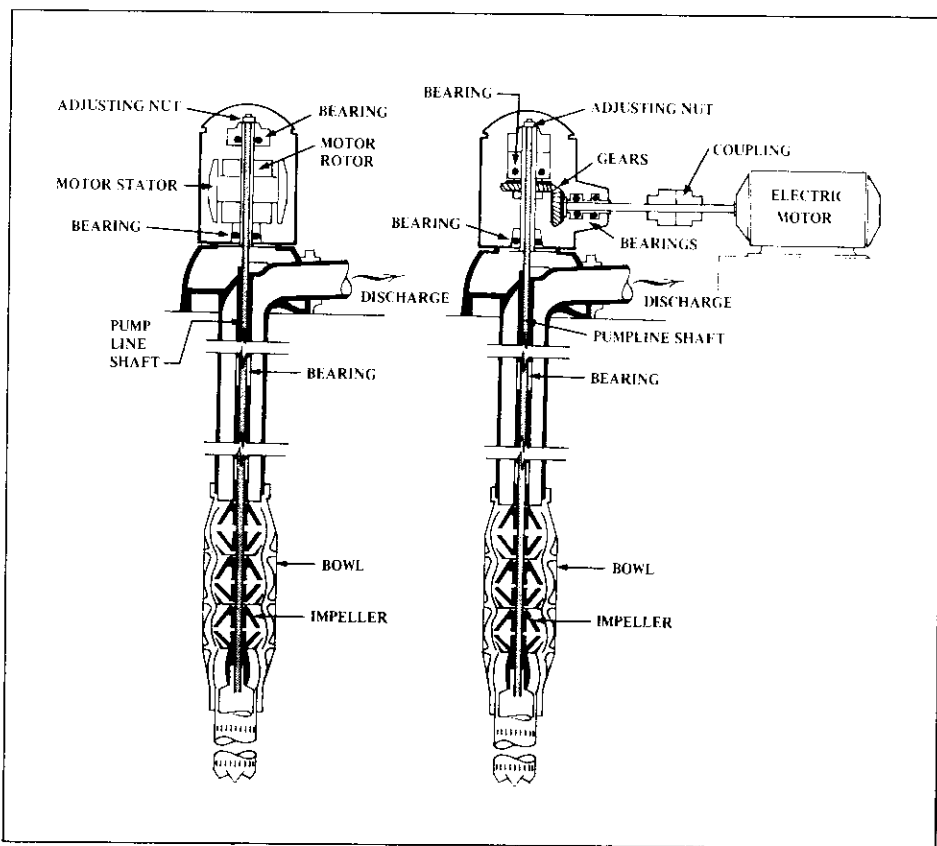


Figure 6. Vertical hollow-shaft electric motor connected to a deep well turbine pump and an electric horizontal shaft motor connected to a right-angle hollow-shaft gear drive and deep well turbine pump. The gear drive unit is also used with internal combustion engines. The hollow-shaft electric motor and gear drive unit have a hollow drive shaft so the pump line shaft extends through them. This is necessary so the impeller adjusting nut is accessible.

between phases. This imbalance causes internal motor heating and is another reason to use a motor with a 1.15 service factor. A 1.15 service factor does not mean the motor can be loaded to 1.15 times the full load rating of the motor.

C. Irrigation Motors Served by Single-Phase Electric Power Supply

Under certain conditions, an irrigation pump may be best served by a single-phase power supply. Two alternatives are available, either a three-phase electric motor served by a phase converter or a special large horsepower, single-phase motor.

Phase converters convert single-phase electric power to three-phase power and may be of either a static or rotary type. "Auto-transformer" type static phase converters are applicable to single motor loads where the load on the pump will remain constant. These may be "balanced out" (the phase amperages to the motor made equal) for a particular motor load.

Rotary phase converters are applicable on either single or multiple motor loads. They are desirable for use where a varying motor load may result, such as where a permanently installed pump may draw from a reservoir which varies in height. They also may be used where several motors will be run from one converter. For example, a

rotary phase converter may be used to run the tower drive motors on an electric drive center pivot system. These motors are constantly starting and stopping. However, rotary converters need a minimum load for proper operation, so one large rotary converter should not be used for both the irrigation pump motor and the pivot drive motors. With this application the pivot drive motors should not be run unless the large pump motor was also operating.

The proper application of phase converters is critical and should only be done in consultation with the manufacturer, pump supplier, and electric power supplier. Always be certain all three leads to the three-phase motor are protected with the correctly sized over-current protection. This will help protect the motor from current imbalance.

Special large single-phase motors which start under reduced current draw are also available in sizes up to 100 horsepower. Because of their design, these special motors may be used on many single-phase lines without adverse effects on other consumers. Again, these are special application type motors and your electric power supplier must be consulted.

D. Motor Starting

1. GENERAL

Electric motors draw more amperage during start-up than when running. Depending on location, this momentary high amperage draw may cause a nuisance to other persons receiving their electricity from the same electric distribution line. This high current draw causes momentary low voltage and consequential dimming of lights, television picture distortion, etc.

To minimize these starting problems, most electric power suppliers require a "reduced-voltage" type starting panel be used with large electric motors. These "reduced-voltage" starters limit

the high amperage draw by the motors during start-up. Four types of reduced-voltage starters are available. The "part-winding" and "wye-delta" types require specially wound motors for their application. The "primary-resistor" and "auto-transformer" types may be used with any induction three-phase motor.

2. AUTOMATIC RESTART

Mechanisms to automatically restart an irrigation pump and system when electric power is restored after an interruption are available. Loss of power may have resulted from load interruption or from interruptions like lightning or other power surges. Automatic restart mechanisms eliminate the need to manually push the start switch to restart the system and can save driving when systems are located many miles from the farmstead.

Automatic restart mechanisms may be factory kits or assembled installations. The actual installation will vary with type of equipment and/or the type of control used with off peak power. Installations will utilize one, two or three timers. Two timers are most common. The first timer is activated when power is restored. After a three to five minute delay the irrigation pump is started, power is restored to the irrigation system and the second timer activated. The second timer runs for another three to five minutes and then activates the low pressure switch, pivot alignment safety and the rest of the safety circuit.

If the pump is normally valved back during startup, automatic restart is not recommended. This may be the situation where long pipelines must be filled with water.

E. Special Provisions for Electrical Installations

1. GENERAL

All installations must be in accordance with the National Electric Code and shall comply with the regulations of the state electrical board. Motors, electrical enclo-

tures, and other electrical equipment must be effectively grounded by a separate grounding conductor suitably connected to the power supply grounding system. On new installations, request for wiring inspection must be submitted to the state electrical board as required.

2. PROTECTIVE MEASURES

- a. Motors shall be supplied through a fused service disconnect. A motor controller (magnetic or manual) and overcurrent protection shall be used.
- b. Overcurrent protection for single-phase motors should be of "single-heater" type with the overcurrent unit in the ungrounded conductor. For three-phase motors use the "three-heater" type to provide overcurrent protection in each of the leads to the motor windings. Rating of the overcurrent protection devices should not exceed 115 percent of the motor nameplate amperage. "Ambient temperature compensated" overload protectors may be used to offset the effect of sunshine on control enclosures.
- c. Inherent overload protection devices which consist of temperature sensing elements buried in the motor windings are highly recommended, but they should not be used in lieu of overcurrent protection unless the motor manufacturer fully guarantees the motor against locked-rotor and overload burn-out with only the temperature sensing element protection.

3. ELECTRIC POWER MONITORS

- a. Electronic electric power monitors are available for a nominal cost. These monitors are wired into the safety circuit of the electric motor and monitor the incoming electric power supply. Factors monitored commonly include loss of any phase, reversed phase sequence and low and/or high voltage on any phase of a three-phase system. If a fault is detected in the incoming power supply, the motor

will be shut off. Since a three-phase electric motor will attempt to run even when it loses a phase, these monitors provide additional protection above that protection afforded by in-line overcurrent protection.

4. MOTOR ENCLOSURE

- a. Motors should be drip-proof type and if operated with the shaft vertical, be designed to be drip-proof in this position unless protected from the weather by other suitable enclosures.
- b. Rodent screens must be installed, either at the factory or in the field at time of motor installation.

5. SECONDARY LIGHTING ARRESTORS

- a. Secondary lightning arrestors should be installed and connected from ground to each ungrounded conductor in the supply, on the secondary side of the transformer but ahead of the service disconnecting means.

V. SAFETY CONTROLS

Safety devices and procedures for protecting the pump and power plant equipment from damage from natural causes, sudden loss of water or power, and errors by operating personnel should be included with every sprinkler system.

Pumping power plants should be equipped with safety devices that shut off the electric motor or engine when there is a break in the suction on centrifugal pumps, or a loss of pressure in the main pipeline. Pumps having water lubricated bearings will be damaged by prolonged operation without water.

Engines used to power sprinkler system pumps should be equipped with safety devices that stop the engine before damage occurs from overload, run-away if the pump becomes disconnected or loses its

prime, loss of oil pressure, or overheating.

A ratchet coupling should be used between turbine pumps and electric motors or engines to prevent reverse rotation of the power plants when the irrigation systems shut down.

Automatic valves that permit pumps to be started or stopped without water damage to high head mainline pipes due to water hammer or surge should be installed as a safety feature.

If the irrigation system will be used for chemigation, the application of any chemicals with the irrigation system, other safety equipment is required. One part of the equipment is a safety interlock, so if the irrigation pump stops, the chemical injection pump will stop also.

an example of the calculation procedure for a diesel power unit using a right angle gear head to drive a deep well turbine pump.

A. Determine the annual ownership costs for a diesel engine and gear-head. Assume an \$8,000 list price for the diesel engine, a \$2,000 cost for the right angle gear head and a 12 percent interest rate. Tables 4 and 5 are used for required factors.

$$\text{ownership cost factor} = \text{depreciation factor} + \text{interest factor} + \text{insurance factor}$$

$$\text{annual ownership cost} = \text{ownership cost factor} \times \text{original list price}$$

$$\text{Diesel engine, ownership cost factor} \\ .067 + .06 + .005 = .132$$

$$\text{Diesel engine, annual ownership cost} \\ .132 \times \$8,000 = \$1,056 \text{ per season}$$

$$\text{Gear head, ownership cost factor} \\ .05 + .06 + .005 = .115$$

$$\text{Gear head, annual ownership cost} \\ .115 \times \$2,000 = \$230 \text{ per season}$$

$$\text{Total annual ownership costs, diesel engine and gearhead} \\ \$1,056 + \$230 = \$1,286 \text{ per season}$$

VI. ESTIMATING THE ANNUAL COST OF OPERATION

The total cost of operation is a combination of the ownership and operating costs. Ownership costs are those associated with owning the power unit and will remain fixed on an annual basis. Operating costs vary from year to year depending on the amount of annual usage.

1. OWNERSHIP COSTS

Ownership costs are a combination of depreciation, average interest on investment and insurance. In this circular we will use straight line depreciation and assume a zero salvage value. The estimated annual ownership cost can be found by adding the depreciation factor, the insurance factor and the interest factor and multiplying the sum of those factors by the original list price of the power unit. See Tables 4 and 5 to find the required factors. The following is

Table 4. Depreciation, Repair and Maintenance, and Insurance Factors.

Power Unit	Expected Life (yr)	Depreciation Factor	Repair and Maintenance Factor	Insurance Factor
Electric	20	.05	.03	.005
Diesel	15	.067	.06	.005
LP gas	15	.067	.06	.005
Gasoline	10	.10	.08	.005
Gear Head	20	.05	.03	.005

Table 5. Interest Factors.

Average Interest Rate	Interest Factor
8%	.04
9%	.045
10%	.05
11%	.055
12%	.06
13%	.065
14%	.07
15%	.075

Note: The interest factor is calculated so that

$$\text{Interest on Investment} = \frac{\text{original cost} - \text{salvage value}}{2} \times \frac{\text{average interest cost}}$$

The salvage value is assumed to be zero

2. OPERATING COSTS

The annual operating costs are a combination of power cost plus repair and maintenance cost. The repair and maintenance cost can be estimated by multiplying the repair and maintenance factor from table 4 times the original cost of the power unit. The power cost can be estimated by calculating the energy demand per hour, the hours of operation per year and the cost of energy per gallon or KWH. The following example shows the calculation of WHP (water horsepower) requirements, water to be pumped, hours of operation per year, energy requirement per hour and finally the cost of energy and then total operating costs per year.

A. As an example, assume a 132-acre center pivot system, requiring 800 gallons per minute at a head of 200 feet. The crop is corn in an area that gets 10 inches of growing season rainfall. Calculate the total energy consumption for both diesel and electricity.

From the formula:

$$\frac{800 \text{ (gpm)} \times 200 \text{ (feet)}}{3960} = 40.4 \text{ WHP}$$

B. From Table 7 we should get 11.9 WHP-hours per gallon of diesel fuel, assuming a right angle gear drive and .88 WHP-hours per KWH for electricity assuming a direct drive.

$$\frac{40.4 \text{ WHP}}{11.9 \text{ WHP-hours/gallon}} = 3.39 \text{ gallons diesel fuel/hour}$$

$$\frac{40.4 \text{ WHP}}{.88 \text{ WHP-hours/KWH}} = 45.9 \text{ KWH/hour}$$

C. From Table 6 we get an average water requirement for corn of 19 inches.

$$\frac{19'' \text{ (total Water requirement)} - 10'' \text{ (growing season rainfall)}}{.85 \text{ (efficiency of irrigation application)}} =$$

10.6'' gross irrigation water to be applied

D. 452 gpm = 1 acre inch per hour (Table 9)

$$\frac{800 \text{ gpm}}{452 \text{ gpm/acre inch/hour}} = 1.77 \text{ acre inch/hour}$$

$$\frac{132 \text{ acres} \times 10.6 \text{ (inches of water)}}{1.77 \text{ acre inch/hour}} = 790 \text{ hours of operation per season}$$

$$790 \text{ hours} \times 3.39 \text{ gallons of diesel/hour} = 2678 \text{ gallons of fuel per season}$$

$$790 \text{ hours} \times 45.9 \text{ KWH/hour} = 36,261 \text{ KWH per season}$$

G. Annual energy cost, assume a diesel power unit and a diesel fuel cost of \$.90 per gallon.

$$2,678 \text{ gallons} \times \$0.90/\text{gallon} = \$2,410 \text{ per season}$$

Table 6. Annual Water Requirements for various irrigated crops in North Dakota*.

Crop	Water Requirements (inches)
Alfalfa	22 — 24
Corn	18 — 19.5
Wheat	14.5 — 16
Potatoes	16 — 18
Sugar Beets	20 — 22

*To determine the irrigation requirement subtract out the effective growing season precipitation and divide the remainder by 0.85 (the application efficiency for the irrigation water).

Table 7. Average Fuel Efficiency on Irrigation Power Units.

Energy Source	Performance in Water Horsepower-Hours (hours per gallon of fuel for various type drives based on 75% pump efficiency)			
	Direct	Right Angle or V-Belt	Flat Belt (straight)	Flat Belt (1/4 or 1/2 turn)
Diesel	12.5 WHP-HR/GAL	11.9 WHP-HR/GAL	10.7 WHP-HR/GAL	9.4 WHP-HR/GAL
Gasoline	8.7 WHP-HR/GAL	8.3 WHP-HR/GAL	7.4 WHP-HR/GAL	6.5 WHP-HR/GAL
Propane	6.9 WHP-HR/GAL	6.6 WHP-HR/GAL	5.9 WHP-HR/GAL	5.2 WHP-HR/GAL
Electricity	0.88 WHP-HR/KWH	0.84 WHP-HR/KWH	.75 WHP-HR/KWH	0.66 WHP-HR/KWH

H. Annual repair and maintenance cost, factor from table 4 is .06 for a diesel engine and .03 for a gearhead.

$$.06 \times \$8,000 = \$480$$

$$.03 \times \$2,000 = \$60$$

Total repair and maintenance cost is \$540 per season

I. Total operating costs are a total of the repair and maintenance costs and the energy cost.

$$\$2,410 + \$540 = \$2,950 \text{ per season}$$

3. TOTAL ANNUAL COSTS

Total costs are the total of annual ownership and operating costs. Following our example with the diesel power unit through, the total costs would be calculated as follows.

Total ownership costs	\$1,286
Total operating costs	\$2,950
Total annual costs	\$4,236

Table 8. Average Fuel Efficiency of Power Units.

Energy Source	Brake Horsepower-Hours Performances in
Diesel	16.7 HP-HR/GAL
Gasoline	11.5 HP-HR/GAL
Propane	9.2 HP-HR/GAL
Electricity	1.18 HP-HR/KWH

Table 9. Irrigation Water Calculation.

1 Acre = 43,560 square feet
1 Cubic Foot = 7.5 gallons
1 AC-IN (acre inch) of water = 24,152 gallons
1 AC-IN per Hour = 452 GPM (gallons per minute)

VII. ESTIMATING POWER REQUIREMENTS

After a pump and power unit have been installed and are running, an estimation of the actual power requirement can be made if the fuel consumption is known. Table 8 gives average fuel efficiencies for power units based on brake horsepower hours per gallon or KWH. Note that this is different than Table 7, which gives fuel efficiency based on water horsepower. The difference between water horsepower and brake horsepower is pump and drive efficiencies.

To estimate horsepower output from the power unit the following formula is used:

- BHP = FC x FE**
- BHP = Brake horsepower**
- FC = Fuel consumption**
- FE = Fuel efficiency (Table 8)**

For example, a diesel power unit is using 4 gallons per hour of fuel, what is the horsepower?

$$4 \text{ gal/hr} \times 16.7 \text{ hp-hr/gal} = 66.8 \text{ BHP}$$

An electric motor is consuming 55 KWH per hour.

$$55 \text{ KWH/hr} \times 1.18 \text{ hp-hr/KWH} = 64.9 \text{ BPH}$$

The electric consumption may be determined by checking the electric meter. On meters which record electrical demand the pointer will indicate consumption in KWH per hour. On electric meters without a demand pointer the electrical consumption can be determined by counting revolutions of the disk and multiplying that by the K_n factor of the meter. The K_n factor indicates how many watts of electricity are consumed each time the disk revolves. To determine KWH/hour energy consumption, use the following formula:

$$\frac{20 \times K_n \times \text{revolutions of disk in 3 minutes}}{1000 \text{ watts/KW}} = \text{EC}$$

For example, an electric meter has a K_n factor of 55 and makes 58 revolutions in 3 minutes.

$$\frac{20 \times 55 \text{ watts/rev} \times 58 \text{ rev}}{1000} = 63.8 \text{ KWH/HR}$$

Note: Some electric power suppliers use the meter multiplier. That multiplier must be multiplied times the K_n factor.