South Dakota Standards for Irrigation Pumps and Power Units

Cooperative Extension, South Dakota State University

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SOUTH DAKOTA STANDARDS for

Irrigation Pumps and Power Units

Cooperative Extension Service
United States Department of Agriculture
South Dakota State University, Brookings
DEFINITIONS

These Terms are Defined as Used in this Publication

Ambient temperature compensated overload protector—an overload protector which is not affected by the change in temperature of the surroundings such as a heat rise due to sunshine on a control enclosure.

Bare engine—The basic engine unit operating at sea level pressure and 60° F. temperature and without accessories such as generator, radiator, fan, air cleaner and water pump.

Brake horsepower—The actual power required to pump a given quantity of water against a given head. It includes all losses except those within the power unit itself and may be calculated by dividing water horsepower by the overall efficiency of the unit.

Cavitation—A condition which exists when the pressure inside the pump falls to the vapor pressure of the water. Local vaporization of the water will then result, causing a hole or cavity in the flow, sometimes accompanied by pitting of the pump surfaces, loss of efficiency, and vibration problems. This may be caused by excessive suction lifts on centrifugal pumps.

Continuous horsepower—The horsepower output that an engine may maintain for long periods of continuous operation without affecting the expected life of the engine. This output will be somewhat less than the maximum available for intermittent operation.

Drawdown—The difference, in feet, between the pumping level and the static level of the source.

Dynamometer—An instrument for measuring the horsepower of an engine usually from the P.T.O.

Dynamic head—The head condition that exists when water is flowing through a system of pipes, etc.

Foot valve—A valve used on the bottom of the suction pipe to maintain water in the pump when it is not in operation. The purpose of the valve is to maintain the pump in a primed condition.

Friction loss—Pressure loss (in feet) due to frictional resistance when water flows through pipe, fittings, orifices, etc.

Head—Synonymous to pressure and visualized as the height of a column of water required to produce the equivalent pressure at its base. As an example, 1 pound per square inch of pressure is equal to a head of 2.31 feet of water or 1 foot of water is equal to .433 pounds per square inch.

Net Positive Suction Head (NPSH)—The total head (in feet) above the vapor pressure of the pumped liquid at the pumping temperature required for proper operation. This term is more fully explained in Part IV of Appendix C.

Overall plant efficiency—The product of the pump efficiency, drive efficiency, and engine efficiency.

Phase converter—A mechanical device which allows a three-phase motor to be operated from a single-phase power supply.

Service factor—A multiplier, determined by the manufacturer, indicating the amount of overload permitted for the motor at rated voltage and frequency. See Part II of Appendix F.

Static head—The difference in elevation (in feet) between the source of supply and the point of free discharge, when there is no flow (sometimes called elevation head).

Total Dynamic Head (tdh)—The total system head when water is flowing through it. It is the sum of the static head, plus the friction loss, plus the pressure at the point of discharge (expressed in feet), plus velocity head, plus the drawdown.

Total Dynamic Suction Lift (TDSL)—The sum of all factors contributing to the total suction lift that the pump must overcome to operate properly. This term is explained more fully in Parts II and III, Appendix C.

Velocity head—It represents the work that must be done by the pump to attain a condition of water in motion through a pipe at a certain velocity. It is equal to the velocity squared divided by two times the acceleration due to gravity.

Vortex—A mass of water whirling in a circular motion tending to form a cavity in the center of the circle and to draw air and debris into this cavity. It is commonly called a whirlpool.

Water horsepower—The theoretical horsepower required to pump a given quantity of water against a given pressure or head at 100% efficiency.

SOUTH DAKOTA STANDARDS for IRRIGATION PUMPS AND POWER UNITS

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Chief Electrical Inspector, State Electrical Board
Retail Farm Equipment Association
How To Use The Standards

The standards for pumps and power units contained in this publication are imperative for the proper selection of the pump and power unit, matching of power unit to the pump, and operation of the basic components of the pumping plant for irrigation purposes. Each section is foot-noted to a particular appendix which contains additional background information and suggestions on each subject. One should be completely familiar with the information contained in these appendices in order to use the standards to maximum advantage.

Introduction

These pump and power unit standards as set forth in this publication include many accepted practices and techniques presently used in South Dakota and in other states where irrigation is practiced extensively. In South Dakota, these standards do not constitute law and should not be considered as such. It is not the intent of these standards to limit or exclude the types of pumps and power units with proper design or proven ability. Future improvement of these components through research and development is strongly encouraged.

The purpose of these standards is to facilitate an understanding between the purchaser and the equipment supplier so that the best possible pump and power unit combination and installation may be obtained for the proposed system. It is also intended to establish a basis of comparison upon which the irrigator may evaluate the efficiency of his system, when first installed and after several years of operation.

In all cases, written contracts and/or memorandums of agreement between concerned parties are recommended which should include such details as: efficiency to be met or exceeded, installation requirements, safety requirements, protective devices to be provided, delivery dates, warranties, and similar items.

It is the aim of this publication to encourage the use of these standards to whatever degree is considered necessary to provide for the most practical and efficient system available.

PUMP STANDARDS

All pumps shall be selected to meet the design requirements for irrigation within the limits of the capacity of the water supply. Manufacturers recommendations for installation, operation and maintenance shall be followed in all cases.

I. Turbine Pumps

A. In a well, the inlet section of the vertical turbine pump shall not extend below the top of the screen except when multiple screened formations are encountered.

B. The pump shall be aligned in the well so that no part of the pump assembly touches the casing.

C. The pump foundation shall have at least 12 inches of bearing surface on all sides of the well. This measurement shall be taken from the outside of the gravel pack.

D. For a discharge greater than 350 gallons per minute, the pump speed shall not exceed 1,800 r.p.m.

II. Centrifugal Pumps

A. The Net Positive Suction Head for a particular pump as specified by the manufacturer shall be exceeded at all times during operation and shall be considered in the selection and installation of the pump.

B. Suction and discharge pipes shall be independently supported to eliminate strain on the pump casing.

C. For a discharge greater than 300 gallons per minute, the pump speed shall not exceed 1,800 r.p.m.

D. The intake end of the suction line shall be submerged to a sufficient depth to prevent formation of a vortex. When sufficient depth is not available, some mechanical means such as a splitter plate shall be used.

E. The maximum velocity through the intake screen shall be 0.5 foot per second.

1See Appendix A for further information.
2See Appendix B for further information.
3See Appendix C for further information.
Ill. Propeller Pumps  
A. The depth of impeller submergence shall be sufficient to prevent mechanical vibration and rapid deterioration of the propeller blades and shall be based on the manufacturer’s specifications.
B. Proper clearance between the end of the suction pipe and the side walls and bottom of the pit shall be determined according to manufacturer’s recommendations.
C. A strainer shall be provided to protect the impeller from floating debris.

POWER UNITS  
I. Standards for Selecting Electric Motors  
To meet the requirements of these standards, electric motor selection and horsepower ratings shall be determined on the basis of design motor loading of not more than 100% of the motor nameplate horsepower rating (for motors of service factor of not less than 1.15), based on data from the pump manufacturer. In actual operation, no motor winding current shall exceed the nameplate amperes.

II. Standards for Selecting Internal Combustion Engines  
To meet the requirements of these standards, the maximum horsepower rating of the bare engine developed by the manufacturer under laboratory conditions shall be corrected as follows:
- 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%
- For drive loss deduct 5%

INSTALLATION STANDARDS  
I. Preliminary Operation and Adjustment  
The supplier shall install the pump and power unit and test operate for a minimum of 12 hours to demonstrate that all parts are in good operating condition, that all adjustments have been properly made, and to familiarize the owner with its proper operation. Proper performance according to manufacturers recommendations for manifold vacuum, oil pressure, r.p.m., and other items shall be established.

II. Information from Supplier  
The supplier shall furnish the purchaser a complete set of specifications on the pump and power unit which shall include:
- A. Rated performance curves for both pump and motor (continuous horsepower curve for internal combustion engines).
- B. Data showing length of column, number, size and type of bowls and depth of bowl setting for turbine and propeller pumps.
- C. Operation and maintenance instructions on both pump and motor.
- D. Cutaway view of pump showing construction.
- E. Warranty for both pump and power unit.
- F. Wiring diagram of electric motor and controls.

III. General Provisions for all Installations  
A. All sites for irrigation power units shall provide a suitable foundation or other means of adequately anchoring or securing the unit in its operating position.
B. An airline probe shall be installed in each well to provide a means of monitoring drawdown levels.
C. A water device shall be installed with each system to record the total quantity of water used and to enable the instantaneous discharge in gallons per minute to be calculated.
D. A pressure gauge shall be installed at the pump for all sprinkler installations.
E. Anti-reverse mechanisms shall be provided for all vertical turbine and propeller pump installations.
F. Protection against loss of pump prime or drop in discharge pressure shall be provided on all electric and internal combustion engine installations.
G. Adequate ventilation shall be provided for all power units to insure proper air movement.

IV. Special Provisions for Electrical Installations  
A. General  
These standards apply to single-phase motors, operated from single-phase supply, three-phase motors operated from three-phase supply, and to three-phase motors operated from single-phase supply through a phase converter. In general, all installations should be in accordance with the national electric code, and shall comply with the regulations of the South Dakota State Electrical Board, Pierre, S. D. Motors, electrical enclosures, and other electrical equipment shall be effectively grounded by a separate grounding conductor, suitably connected to the power supply grounding system. On new installations, request for wiring inspection shall be submitted to the State Electrical Board as required.

B. Protective Measures.  
1. Motors shall be supplied through a fused service disconnecting means. A motor controller (magnetic or manual) and overcurrent protection shall be used.
2. Overcurrent protection for single-phase motors shall be of the “2-heater” type (2 current-sensing devices) and for three phase motors of the “3-heater” type to provide overcurrent protection in each of the leads to the motor windings. Rating of

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4See Appendix D for further information.
5See Appendix E for further information.
6See Appendix F for further information.
7See Appendix G for further information.
the overcurrent protection devices shall not exceed 125% of the nameplate amperes for motors with not over 40 °C. temperature rise and service factor of 1.15 or greater. The rating shall not exceed 115% of nameplate amperes for all other motors. *Ambient temperature compensated* overload protectors shall be used to offset the effect of sunshine on control enclosures.

3. Inherent overload protection devices which consist of temperature-sensing elements buried in the motor windings are highly recommended, but shall not be used in lieu of overcurrent protection described above unless the motor manufacturer fully guarantees the motor against locked-rotor and overload burnout with only the temperature sensing element protection.

4. No-voltage dropout shall be provided to prevent undesirable instantaneous restarts after a momentary outage. Automatic restart with suitable time-delay control may be used.

C. Motor Enclosures
1. Motors shall be a 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.

Table 1. South Dakota Standards for Fuel Consumption

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Direct</th>
<th>Performance Standards in water-horsepower-hours per gallon of fuel for various type drives*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Right Angle or V-Belt*</td>
</tr>
<tr>
<td>Diesel</td>
<td>11.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Gasoline</td>
<td>8.5</td>
<td>8.0</td>
</tr>
<tr>
<td>Tractor Fuel</td>
<td>7.7</td>
<td>7.4</td>
</tr>
<tr>
<td>Propane</td>
<td>7.0</td>
<td>6.6</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>65.0/1000</td>
<td>61.0/1000</td>
</tr>
<tr>
<td></td>
<td>cu. ft.</td>
<td>cu. ft.</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td>0.88/KWH</td>
</tr>
</tbody>
</table>

*See Appendix H for sample calculations using this table.

SAFETY

A. All shaft and belt drive installations shall be shielded to prevent injury to a person accidentally coming in contact with them.

B. Fans on internal combustion engines shall be adequately shielded to prevent injury to a person accidentally coming in contact with them.

C. All electrical installations shall meet the safety requirements of the electrical code.

APPENDIX A

Pump Selection and Power Requirements

Every installation requires the selection of the proper pump to meet the desired conditions of pressure and discharge. Each pump type and model is laboratory tested to develop a set of curves which show its operating characteristics.

Improperly selecting a pump that will not operate at or near its maximum efficiency may require added power, resulting in excessive fuel requirements.

Future changes in the delivery system may also require a change of pumps.

To determine the actual horsepower of the power unit used in driving a pump, it is necessary to know the efficiency of the pump, the type of drive, type of power unit, the head under which the pump operates, and all losses in the piping system. The manufacturer will make guarantees on efficiencies that can be obtained for the pumps he proposes to furnish. These
efficiencies can be checked in the field under actual working conditions by running a series of tests.

The efficiency of a horizontal centrifugal pump and a vertical centrifugal pump mounted in a dry well includes only the losses in the pump proper. The efficiency of a deep-well turbine pump includes all losses from the intake at the end of the bowls to the discharge outlet. If the power unit and pump are not directly connected, there is a “drive” loss that must be considered. These losses are well-enough established to enable accurate assumptions to be made for the various types of drives that are in common use. (Refer to Appendix H—Pump Drives).

The useful work done by a pump or the water horsepower (WHP) required is expressed by the formula:

\[
WHP = Q \times \text{total dynamic head (feet)} / 3,960
\]

The water horsepower represents the power that would be required to operate the pump if the pump and drive were 100% efficient.

The brake horsepower (BHP) required to operate a pump is determined by the formula:

\[
BHP = \frac{\text{water horsepower (WHP)}}{\text{pump efficiency} \times \text{drive efficiency}}
\]

**APPENDIX B**

**Vertical Turbine Pumps**

For a deep well and for capacities above approximately 100 gallons per minute, the most widely used irrigation pump is a “vertical turbine.” It consists of four major components:

1. **Bowl assembly**—this contains one or more impellers, each in its own housing.
2. **Column and shaft assembly**—this consists of the pipe to suspend the bowl assembly in the well and convey the water to the surface. Inside this pipe (or column) is the shaft which connects the impeller to the driver located at ground level. The shaft may be either water lubricated or oil lubricated.
3. **Discharge assembly**—this often is called the “head” or “base.” It is normally cast iron, designed for installation on a foundation. It supports the column and shaft assembly and the bowl assembly in the well and provides a discharge for the water being delivered. It also accommodates the driver for the pump.
4. **Driver**—this may be either an electric motor or a right angle gear for connection to a power unit. When an electric motor is used the usual type is a vertical hollow shaft design which permits the pump shaft to come up through its center for securing at the top. The right angle gear is also normally of the hollow shaft type for the same reason. It also has a horizontal shaft for connection to the engine drive or power take-off. The internal gears are available in various ratios in order to accommodate an engine with an operating speed which is different from the desired pump operating speed.

Because of the limited diameter of its impellers, each one develops a relatively low pressure or head and in order to develop the required pressures for the average application it is necessary to stack several impellers in series one above the other with each in its own bowl or diffuser housing. This is called staging and only increases the head or pressure and not the discharge. Thus, a four-stage bowl assembly containing four impellers all attached to a common shaft through the separate housing or bowls will develop four times as much pressure but will have the same discharge. The bowl shaft is attached to the line shaft through the center of the pump column pipe and must have a length as necessary to locate the bowl assembly below the level of the water in the well.

**APPENDIX C**

**Centrifugal Pumps**

I. **General**

If the source of water is a surface supply, such as a lake, stream, or other body of surface water, the pump most commonly used is the horizontal centrifugal type, commonly referred to as a centrifugal pump. This is one in which the shaft is normally in the horizontal position. This type is usually subdivided into two groups, single suction (end suction), and double suction (often called split case). Either of these may be single or multistage; that is, they may have only one impeller or they may have two or more impellers so constructed that the water in passing through the pump is conducted from the discharge of one impeller to the suction of the second and thus the total pressure or head is that developed by a single impeller multiplied by the number of impellers in the pump.

The most common pump and the lowest in cost is the end suction, single stage. Available sizes vary considerably with different manufacturers. In general, if the desired performance exceeds about 1,000 gallons per minute of capacity and 150 feet of head, consideration should be given to the split-case type which is more rugged in construction and is capable of a much greater range of performance.

II. **Suction Limits**

Among the most important factors controlling the satisfactory performance of a centrifugal pump are the suction conditions. Excessively high suction lifts will usually reduce the capacity and efficiency of the pump and may lead to serious trouble through vibration and cavitation. To avoid this, the total dynamic suction lift (TDSL) of a suction system may be calculated and compared with TDSL limits shown on the performance curve of the pump.
III. Calculation of TDSL

The total dynamic suction lift is the sum of the following four values:
1. The vertical distance (in feet) from the pumping water level to the center of the impeller eye.
2. The friction loss (in feet) in the suction system (pipe, valves, fittings, foot valve, etc.) calculated from a friction loss table.
3. The velocity head (in feet) in the intake pipe. This velocity head is equal to the velocity of the water (in feet per second) squared, divided by two times the acceleration due to gravity or:

\[ \text{Velocity head} = \frac{V^2}{2g} \]

where "D" is the inside diameter of the suction line in inches and g.p.m. is the discharge in gallons per minute.
4. A temperature and altitude correction. The standard values are 70°F water temperature and sea level altitude. An increase of temperature or altitude will decrease the suction lift ability of the pump. The correction factor for 40°F to 70°F water temperature is 1.2 feet for every 1,000 feet of elevation change and is to be added to the total suction lift.

The TDSL that is present in the suction system of the pump must be less than the TDSL value shown on the pump performance curve. If the TDSL is too high, it may be reduced by decreasing the vertical distance that the water is lifted, and by increasing the size of the suction pipe, which will reduce the friction loss and the velocity head.

IV. Net Positive Suction Head

The net positive suction head (NPSH) is another term found on performance curves for centrifugal pumps. The NPSH required by a pump is the total head (in feet) above the vapor pressure of the pumped liquid at the pumping temperature. The required NPSH does not change with temperature or elevation. The required NPSH may be found by subtracting the calculated TDSL value from 33 feet. For proper performance, the difference must exceed the NPSH shown on the pump performance curve.

APPENDIX D

Propeller Pumps

Propeller pumps are used only from surface sources and are usually used where large volumes of water often containing sand must be pumped against heads of less than 25 feet.

There are two types of propeller pumps, the axial-flow or screw type, and the mixed flow. The major difference between the axial-flow and the mixed-flow propeller pump is in the type of impeller.

The principal parts of a propeller pump are similar to the deep-well turbine pump in that they have a head, an impeller, and a discharge column. A shaft extends from the head down the center of the column to drive the impeller. Some manufacturers design their pumps for multi-stage operation by adding additional impellers where requirements demand higher heads than obtainable with single-stage pumps.

Where propeller pumps are adapted, they have the advantage of low first cost and the capacity to deliver more water than the centrifugal pump for a given size impeller. Also, for a given change in pumping lift, the propeller pump will provide a more nearly constant flow than a centrifugal pump. Their disadvantage is that they are limited to pumping against low heads.

Power requirements of the propeller pump increase directly as the head increases so adequate power must be provided to drive the pump at maximum lift. There is some tendency for a propeller pump to overload as head is increased. For this reason, it is important to select a motor which will provide ample power to drive the pump through the entire range of conditions due to change in water level or discharge pressures. Propeller pumps are not suitable under conditions where it is necessary to throttle the discharge to secure reduced delivery. It is important to accurately determine the maximum total head against which this type of pump will operate.

Propeller pumps are not suitable for suction lift. The impeller bowl must be submerged with the pump operating at the proper submergence depth. Different sizes of pumps require different submergence depths. Therefore, the specifications as stated in the standards, must be followed.

Propeller pumps also have an application in providing operating pressure for gated pipe on an installation that has been converted from a ditch system and where the water supply is still gravity fed.

APPENDIX E

Power Units

Most irrigation pumps are powered by either electric motors or internal combustion engines. The source of power that is best suited for a specific installation depends on certain physical and environmental factors. The power-unit selection should be made only after considering the following:

1. The amount of brake horsepower required for pumping.
2. Hours of operation per season.
3. Availability and cost of energy or fuel. (In case of electricity, availability of single-phase or three-phase power may influence selection.)
power to the requirements of the pump. Efficiency is sacrificed with both electric and internal combustion great excess of power above the actual needs. Previously used power units should be carefully checked from an operating standpoint than the most expensive engines if the power plant is designed to deliver a and evaluated as to condition, available horsepower, and speed. The efficiency of a unit in only fair mechanical condition often does not exceed 50%. The use of an old, misfit power unit can be more costly power if protections are provided including dry adequate shelter from the elements, and safety devices against overloading, undervoltage, or excessive heating. Advantages of the electric power are relatively long life of the motor, low maintenance costs, dependability, and ease of operation. An electric motor also will deliver full power throughout its life and can be operated from no load to full load without damage. Some of the disadvantages of electric power are the limited size motors which can be used when only single-phase current is available, power interruptions, and the necessity of constructing an electric supply line to all pumping locations. In some areas, phase converters are used to partially overcome the disadvantage of single-phase current.

**APPENDIX F**

**Electric Motors**

**I. General**

An electric motor, properly selected and protected, can be expected to supply many years of trouble-free power if protections are provided including dry mountings, rodent protection, good ventilation, adequate shelter from the elements, and safety devices against overloading, undervoltage, or excessive heating. Advantages of the electric power are relatively long life of the motor, low maintenance costs, dependability, and ease of operation. An electric motor also will deliver full power throughout its life and can be operated from no load to full load without damage. Some of the disadvantages of electric power are the limited size motors which can be used when only single-phase current is available, power interruptions, and the necessity of constructing an electric supply line to all pumping locations. In some areas, phase converters are used to partially overcome the disadvantage of single-phase current.

**II. Service Factor**

In the design and selection of electric motors the standard service factor of 1.15 should not be utilized but left as a “safety factor” against adverse conditions which may occur such as high operating temperatures, voltage unbalances, voltage fluctuation, variation from design loading, and changes of loading with operation.

The heating effect in a motor winding varies with the square of the amperes; thus, a motor current 15% over nameplate amperes will produce 32% more heat in the windings. It is estimated that a motor winding temperature 10° C. too high cuts the life of the motor in half.

**III. Three-phase motors on Single-phase Supply Supplied by Phase Converter**

Selection of horsepower rating of a three-phase motor for use with a phase converter should be done with care and consideration to the characteristics of the motor-converter combination to be used.

With a “capacitor-type” phase converter, motor winding currents may be unbalanced and some may be excessive. At less than rated loads, the winding connected to the capacitor phase may carry excessive current. It may be necessary to select a motor size based on loading to 75% to 85% of the nameplate rating, then change capacitance of the running capacitors to reduce current in this phase. The “transformer-capacitor” type converter can provide nameplate horsepower with balanced motor currents not over nameplate amperes, but is affected by fluctuating voltages and loads and may need to be loaded somewhat conservatively.

**APPENDIX G**

**III. Horsepower Ratings**

The general fuels for internal combustion engines are gasoline, diesel, propane and natural gas. Manufacturers have developed performance curves for each of their engines which show horsepower rating at various speeds and are used as a basis for 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. Because of the characteristics of internal combustion engines, it is also necessary to further correct the horsepower curve to compensate for continuous loading which is required in irrigation pumping. Figure 1 shows how a horsepower vs. r.p.m. curve is changed after corrections are made for accessories and continuous operation.

Some manufacturers publish both the dynamometer curve and the continuous brake horsepower curve in their literature. When only one curve is shown, that curve will generally be the horsepower determined by a dynamometer under laboratory conditions. In this case the corrections listed in the section on Power Units will apply.

Brake hp. rating (at recommended speed) will be normally 1.4 to 1.6 times actual hp. load.

The best operating load for an internal combustion engine is at or near the continuous brake horsepower curve. Running an engine under lighter loads usually results in poor fuel economy for the water delivered, since too much horsepower is used in overcoming engine friction and throttling losses. Running it wide-open throttle invites engine trouble as well as excessive fuel consumption.
II. Cooling Jackets

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

In some instances, however, heat exchangers may be used on installations in sheltered areas where air movement around the unit is very poor and where the source of water is reasonably warm. This situation will require the use of larger size heat exchanger than normally recommended. Addition of a fan to move hot air away from the engine may increase fuel consumption slightly but will eliminate safety switch shut downs during extremely hot weather.

APPENDIX H

Sample Calculations Using Table 1.

Assume a direct drive diesel pumping plant delivers 900 gallons per minute against a head of 200 feet. Using the formula (see Appendix A) for water horsepower (WHP), we have the following:

\[
WHP = \frac{900 \text{ g.p.m.} \times 200 \text{ feet}}{3,960} = 45.5 \text{ WHP}
\]

From Table 1 this plant should get 11.0 WHP-hrs per gallon of fuel. Then, to find the maximum fuel consumption to meet South Dakota standards we divide as follows:

\[
\frac{45.5 \text{ WHP}}{11.0 \text{ WHP-hrs/gal.}} = 4.1 \text{ gallons per hour.}
\]

Pump Drives

The four common types of pump drives are the right angle drive, V-belt drive, flat belt drive and direct drive. Each has its own rules and guidelines which will be discussed here.

Right Angle Drives

The main considerations for this drive is shaft alignment. Based on Nebraska EC 57-701, the following guidelines are given.

1. Yoke A and B must be lined up in the same plane when pump shaft and engine shaft are parallel. (See figure 2 and case A of figure 4) otherwise undue vibrations will occur in the drive shaft.

Figure 1. Horsepower vs. r.p.m. curve for internal combustion engines.
2. Looking from the top down on the installation, the drive shaft, the engine, and the gear head should all be in a straight line (figure 2).

3. Pump should be fastened firmly to its base to prevent misalignment.

4. To enable uniform wear over the needle bearings on the drive shaft, the maximum value for distance B in figure 3 is shown in the tabulation at bottom left of figure with the corresponding values of distance A, (the length of the drive shaft). Other configurations for shaft alignment are shown in figure 4.

5. Shafts of engine and gear head must be parallel.

6. Universal joints, in pairs, can be aligned so that the angular fluctuations of the joints will cancel each other.

7. If the shafts connected to one of the universal joints are in a different plane than the shafts connected to the other universal joint, the yoke on the intermediate shaft should be placed out of line by an amount equal to the angle between the planes.

8. Oil should be changed in the gearhead every 1,000 hours of operation. Follow manufacturers recommendations for type of oil or as a guideline use a high grade turbine oil of 300 viscosity at 100°F. for winter and 500 viscosity at 100°F. for summer.

V-Belt Alignment

1. Always use deep groove sheaves (pulleys) on quarter turn drives.

2. Always use a set of matched belts. If one belt breaks you must replace all belts with a matched set.

3. Center line of pump pulley should be in line with center line of power unit pulley as shown (figure 5).

4. Direction of rotation must be such that the tight side of the belts will be on the bottom.

5. It is recommended that the pulley size be not less than 9 inches in diameter for "C" belts.

6. Center line of pulley on engine should be offset a distance Y as shown in sketch (figure 6).

7. All V-belt pump drives should be engineered for length of belt, pulley size, and number of belts.

8. A maximum of 7 belts are allowed for a quarter turn drive because the distance between the point
Correct PTO shaft alinement

INCORRECT PTO SHAFT ALINEMENT

Sketches from Michigan State University - Extension Bulletin 338

Figure 4. Correct and incorrect power-takeoff shaft alignment.
where the belts leave the driven pulley and enter the drive pulley is not the same and it is not possible for all belts to have the same tension. This condition is one reason why it is not permissible to have a distance less than 60 inches between pump pulley and power unit pulley on a two-belt quarter turn drive.

**Direct Drive for Electric Installation**

1. Before operating, start motor momentarily to check for correct rotation.
2. Put in key, put on the adjusting nut, pull up pump shaft according to manufacturer’s instructions, then insert set screws.
3. Oil and grease should be changed at least once a year. High grade turbine oil should be used; 300 to 400 viscosity at 100°F for winter and 500 to 600 viscosity at 100°F for summer operation.

**Quarter Turn Flat Belt Drives**

1. Pulley faces, diameters, and belt thickness should be in accord with belt manufacturer’s recommendations.
2. Belts should be at least 1 to 2 inches narrower than pulley faces to prevent possible damage to belts from rubbing against supports.
3. Quarter turn drives should be designed to run with slack side on top. Belt must always lead straight into the pulley.
4. Do not add more tension to belt than is necessary to pull the load. An excess of 10% in tension will decrease belt life 60% of its rated life.