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EC71-799 Engineering the Irrigation Pumping Plant

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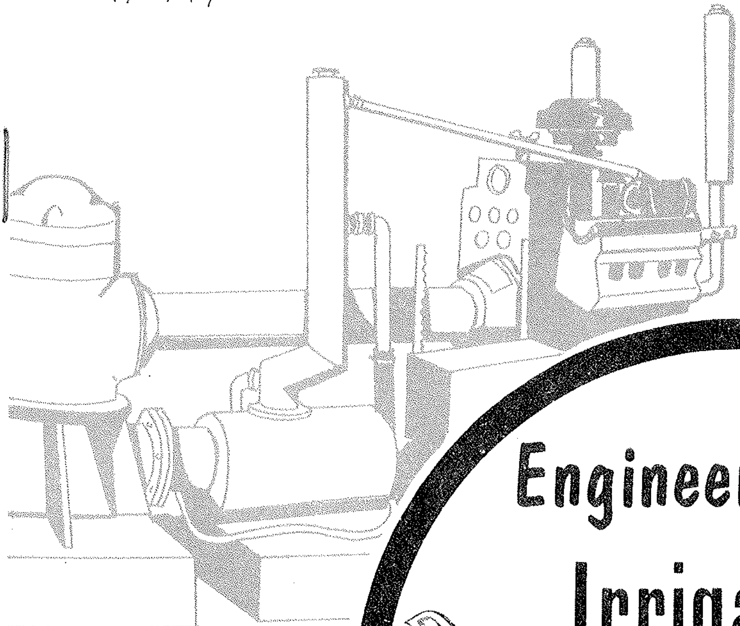

Engineering the Irrigation Pumping Plant

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Engineering the Irrigation Pumping Plant

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You will get water for the most acres at the least cost from your irrigation pumping plant when engine, drive, pump, and water distribution system are matched.

Any change in the system usually requires a change in some or all of the units. For example, a switch from surface to sprinkler system requires a change in the pump and drive and may require a change in the engine.

A rule to follow is that any change in any of the units of a system requires a look at the other units in the system to be sure they still match. Any mismatch can increase the cost of pumping water.

The bowls, line shaft, column, and pump head of a pumping plant must all be matched for amount of water to be pumped. The bowls should have the correct head characteristics or develop the pressure needed to pump the amount of water wanted. The column and pump head must not offer much resistance to the flow of water and the line shaft should be the right size so impellers will operate properly.

The pump drive that has the proper speed ratio will result in the correct speed for engine and pump. An incorrect ratio could result in an overspeeded or an overloaded engine.

The power output of an engine at the selected speed matched to the power requirement and speed of the pump results in the most gallons of water pumped for each gallon of fuel.

Pumps

An impeller for a turbine pump that will move the amount of water needed when run at the selected speed will have the efficiency shown by the manufacturer's specifications. A study of the manufacturer's impeller curves is necessary for the best selection.

Information that can be obtained from the curves is: (1) gallons per minute, (2) revolutions per minute, (3) head per stage, (4) efficiency in percent, (5) brake horsepower per stage (Fig. 1). One piece of this information gives a corresponding reading for the other information required. The total head and gallons per minute are usually known. This information is used in locating other impeller information on the curves.

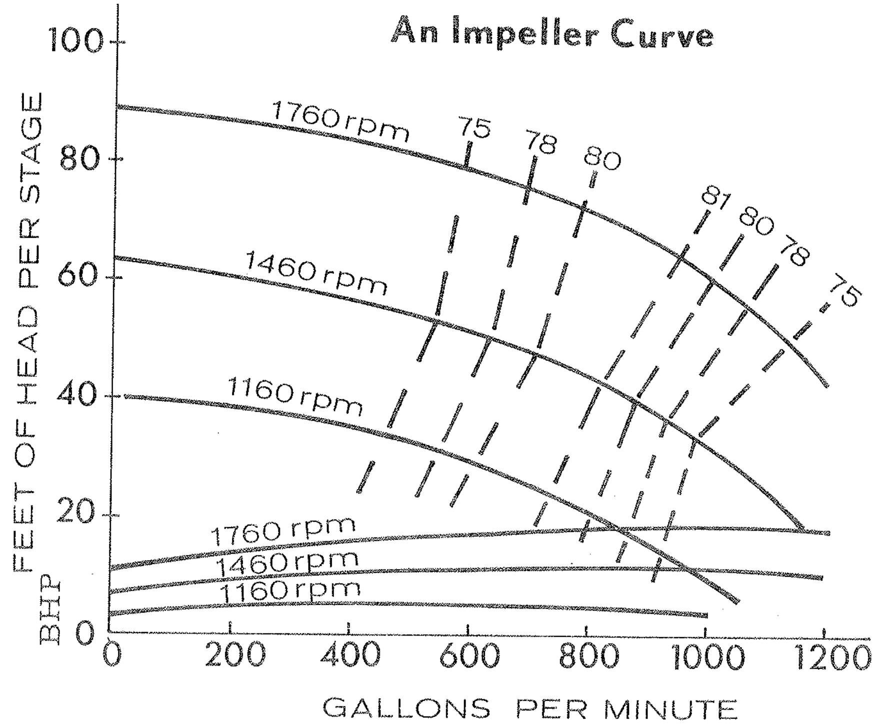


Fig. 1

The head required at the bowls to force water to the surface and through the distribution system—pumping head—determines the number of bowls needed in the pump. For reasons of economy and efficiency, select an impeller which will give the desired gallonage, head, pump speed, and efficiency with a minimum number of bowls.

Pump Drives

The direct drive on either an electric or an internal combustion engine fixes the speed of the pump and the power unit at a 1:1 ratio. With the right angle drive, or belts, the ratio of the pump speed to engine speed depends on the gear or pulley ratio.

The ratios given in manufacturer's literature on right angle drives gives the engine speed followed by the pump shaft speed.

For example, a ratio of 5:4 shows an engine speed that is 5/4 or 1 1/4 times the pump shaft speed. This can also be read as a pump shaft speed that is 4/5 times the engine speed.

Pulley size ratios for a V-belt drive are given in the same way. Engine speed is given as the first number in the ratio. However, with V-belt, the ratio refers to the pitch diameter (effective diameter of a loaded pulley).

Setting Up Quarter Turn Drives

1. Always use deep groove sheaves (pulleys) on quarter turn drives.
2. Always use a set of matched belts.
3. Center line of pump pulley should be in line with center line of power unit pulley as shown (Fig. 2).

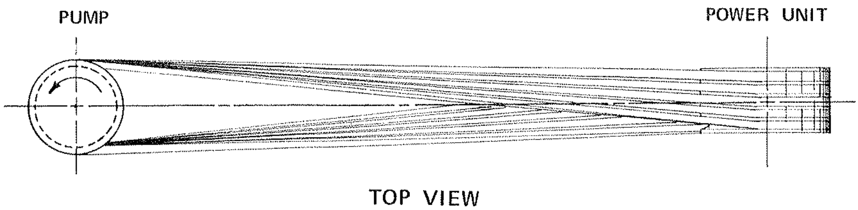
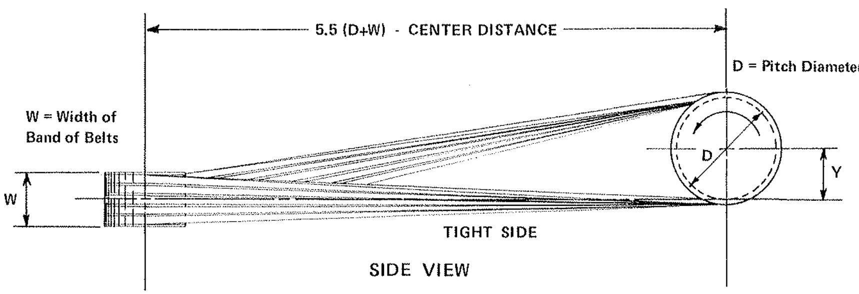


Fig. 2

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 (Fig. 3).



CENTER DISTANCE	"Y" DIMENSION	CENTER DISTANCE	"Y" DIMENSION
60"	2½"	160"	6½"
80"	2¾"	180"	7¾"
100"	3"	200"	9"
120"	4"	220"	10½"
140"	5¼"	240"	12"

As recommended by Rubber Manuf. Assoc. and Multiple V-Belt Drive and Mechanical Power Transmission Assoc.

Fig. 3

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

Attention to gear ratios and the drive shaft alignment are important in setting up a gear drive. The careful selection of the gear ratio will give the engine speed desired to get the recommended pump speed. Also, the shaft should be carefully aligned so angularity in either the horizontal or vertical direction does not exceed five degrees. Then the power loss through the drive would not exceed five percent.

Power Units

Internal Combustion

The power unit on an irrigation pumping plant must supply power to lift water, build pressure, overcome power losses in pump and drive, and run the power unit accessories under the atmospheric conditions at the well location.

An internal combustion engine has many accessories so the usable power is considerably less than the maximum brake horsepower of a stripped engine without accessories. Therefore, take care in reading engine curves and specifications. Know what accessories are on the engine at the time the engine test was run and what effect other accessories not included at the time of the test will have on useable power. Engine manufacturers do not use the same test code for their engine tests. Find out about test conditions, what accessories were used, and the elevation and temperature during the test.

Engine Curves

Several horsepower curves may be given: maximum, continuous, and intermittent. One or all of these curves may be shown on the same sheet. Since the maximum horsepower curve is the most important, be sure the right curve is used when reading horsepower from a curve (Fig. 4).

The maximum brake horsepower, derated for continuous duty, elevation, temperature, accessories not included in the engine test report, and drive efficiency should equal the water horsepower output of the pump.

An estimate of the maximum brake horsepower of an engine can be obtained when the engine displacement and the revolutions per minute are known. Engine displacement times the r.p.m. divided by a factor to use with different fuels is: gasoline or LPG, 8000, Diesel, 8700. The calculated result should be within ± 10% of the manufacturer's rating or further checks should be made.

For example, to estimate the horsepower of a 400 cubic inch gasoline engine which has a rated speed of 2,000 r.p.m. using the above formula, proceed as follows:

$$\frac{400 \times 2{,}000}{8{,}000} = 100 \text{ h.p.}$$

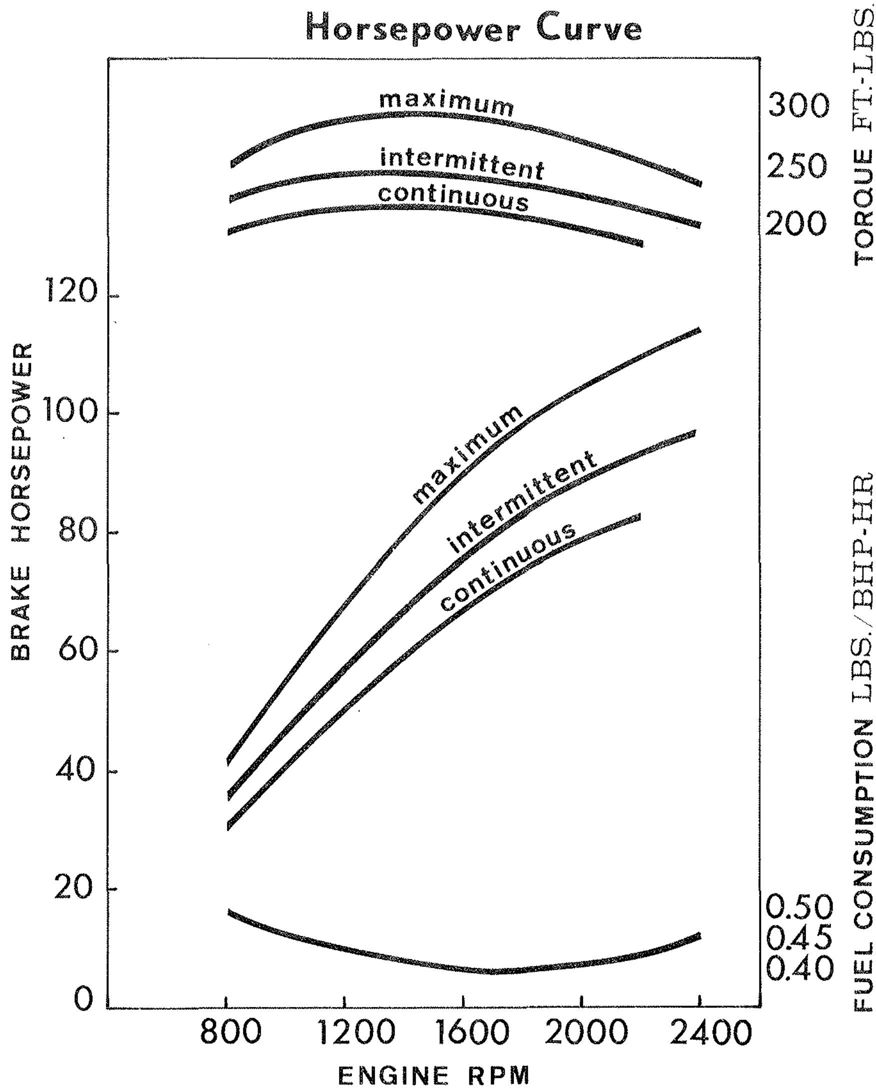


Fig. 4

Water, site, atmospheric conditions, pump drive, and power unit requirements have been discussed. However, engine speed and engine torque should be considered.

Fifteen hundred feet per minute piston travel has been considered a limit to engine speed for long engine life. Many engines have a piston speed higher than

1500 feet per minute. This may be a point for discussion in engine selection.

Torque characteristics at the selected engine r.p.m. should be determined since the torque and speed determine the engine power output.

Electric Motors

The nameplate power output of an electric motor should be closely matched to power requirement of the pump when a direct connected drive is used. If other pump drives are used, then the drive loss should be considered. There is no object in oversizing an electric motor as the original investment is higher and no operating saving is gained; also, standby charges may be greater.

Step-by-Step Procedure for Matching Internal Combustion Engine to Pump

This information may best be explained by an example based on the following conditions:

Static water level	80 ft.	(1)
Pumping rate	1000 g.p.m.	(2)
Pumping water level	100 ft.	(3)

From the farm field make-up, cropping system, and water supply, the decision was made to use 5-1320 ft. tow-line sprinklers which require 65 p.s.i. pressure at the pump.

The information is now available to select a pump impeller and bowl assembly for an 8" pump.

Pumping rate is given	1000 g.p.m.	(2)
Total pumping head in feet is calculated as follows:		
pumping water level to surface	100 ft.	(3)
converting p.s.i. to ft. 65 x 2.31	150 ft.	(5)
total head	250 ft.	(6)

From the manufacturer's curves, an impeller is selected that will deliver 1000 g.p.m., at a 65 ft. head, at 75% efficiency, and at 1760 r.p.m. However, the total head is 250 ft. Then, 250 divided by 65 gives (3.85) 4 bowls required.

The water horsepower output of the pump at 1000 g.p.m. and 250 ft. head is:

$$\frac{250}{3960} \qquad \frac{(2) \times (6)}{3960} \qquad 63 \text{ w.h.p.} \quad (7)$$

where 3960 is a factor for determining water horsepower.

Because of the location relative to electric lines, the decision was made to use an internal combustion engine. Since there was no particular preference as to make of engine, the engine was selected on the basis of first cost, fuel economy, and maintenance providing the engine would match properly with the pump:

The w.h.p. output of the pump	63	(7)
The elevation and temperature at the well site		
elevation	2000 ft.	(8)
temperature, max. intake	110° F.	(9)

Engine, derating

no derating for accessories

(on engine during test)

continuous duty 0.75 (10)

Elevation, 3% for each 1000 ft.

1.00-0.06 0.94 (11)

Temperature, 1% for each 10^{o} above 60^{o} F

110-60 = 50

50/10 x 0.01 = 0.05 0.95 (12)

Drive efficiency, gear head 0.95 (13)

Drive efficiency, V-belt 0.95

Pump efficiency 0.75 (14)

Then the maximum brake horsepower required is:

$$\text{b.h.p.} = \frac{63}{.75 \times .94 \times .95 \times .95 \times .75} \quad \text{or} \quad \frac{(7)}{(10) \times (11) \times (12) \times (13) \times (14)}$$

$$= \frac{63}{0.477} \quad \text{or} \quad 132 \text{ b.h.p.}$$

A shortcut method is to multiply the w.h.p. by 2. This gives about the same result: 63 x 2 or 126 b.h.p.

Natural gas was available as the engine fuel. An engine was found that developed 132 maximum h.p. and operated at 2200 r.p.m. We know the pump speed is 1760 r.p.m. and the engine speed is on top in the gear head ratio so that the gear ratio is 2200/1760 or 5/4 (15).

The matched components of the pumping plant have been selected. An 8" pump with four bowls to supply 1000 g.p.m. of water to 5-1320 ft. tow-line sprinklers. The pump will be operated by a 132 h.p. natural gas engine that runs at 2200 r.p.m. A gear head with 5/4 gear ratio will run the pump at 1760 r.p.m. for an engine speed of 2200 r.p.m.

Step-by-Step Procedure for Matching an Electric Motor to an Irrigation Pump

The amount of water and total head with other conditions for the pump and drive are the same as in the previous example on matching an internal combustion engine. This includes steps 1-7.

In step 7 we found 63 w.h.p. for 1000 g.p.m. and head of 250 ft.

Because of a location near an electric transmission line, a 3-phase power line to the pump site is economical. Therefore, an electric motor is decided on as the power unit.

w.h.p. output of the pump		63 (7)
temperature at the well site, maximum 100^{o} F. is acceptable for an electric motor		
drive efficiency, direct drive		
no loss for the drive—direct coupled		1.00 (16)
pump efficiency		0.75 (14)
motor size = $\dfrac{63}{1.00 \times 0.75}$	$\dfrac{(7)}{(16) \times (14)}$	84 h.p. (17)

It is permissible to have a continuous 10% overload on an electric motor. This difference between 84 and the next smaller motor (75) exceeds the 10% overload limit for an electric motor. Since there is no 85 or 90 h.p. electric motor, a 100 h.p. 1760 r.p.m. motor is needed for this pump.

A slight adjustment could be made in the output of the sprinklers so the 75 h.p. motor would do the job within the overload limit; i.e., a reduction of 0.02 inch per hour per nozzle brings power unit output down to 77 h.p. which would be approximately 3% overload on the 75 h.p. motor.