Using Your Records to Locate Inefficient Pumping Plants

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Pumping Plant Performance

The Nebraska Pumping Plant Criteria

The University of Nebraska established a performance criteria for pumping plants, based on field tests of pumping plants, lab tests of engines and manufacturer data on three-phase electric motors. The criteria is commonly referred to as the Nebraska Pumping plant Criteria (NPC). A pumping plant meeting the NPC is delivering the expected amount of useful work*, measured as water horsepower hours (whp-h),* for the amount of energy consumed.

The NPC should be thought of as a reasonable target for every new pumping plant. It is possible for a well-designed pump coupled to an efficient power unit to exceed the NPC. In fact, large scale pump testing projects have found around 10% of pumping plants in the field that are performing over 100% of the NPC.

The NPC (Table 1) is stated in terms of horsepower-hours of work input into the pump shaft and in terms of the water horsepower hours (whp-h) produced per unit of energy consumed. Stating performance in these terms makes it possible to compare the performance of all pumping plants using a given energy source, regardless of pumping rate, lift, and system pressure.

Table 1. The Nebraska Pumping Plant Performance Criteria (NPC)

Energy Source	hp-h / energy unit[a]	whp-h/energy unit[b]	Energy units[c]
Diesel	16.66	12.5	Gallons
Gasoline	11.50	8.66	Gallons
Propane	9.20	6.89	Gallons
Natural gas (mcf)[d]	82.2	61.7	MCF
Natural gas (therm)	8.9	6.67	Therm (100,000 BTU)
Electricity[e]	1.18	0.885	kWh

The author personally conducted over 200 pumping plant tests in Kansas and Nebraska from 1978 to 1981. The most surprising finding was producers generally did not know when a pumping plant was inefficient until they received the test results, even when the pumping plant test showed it was using 30 to 50 percent more energy than expected by the NPC. The reason producers couldn't recognize poorly performing pumping plants is they almost never have two pumping plants operating under the same pumping conditions of volume, lift and system pressure. They therefore didn't have any way to judge the relative performance of a given pumping plant vs. others.

How to use long term records to locate inefficient pumping plants

Four large-scale pumping plant studies in the 1950s, 60s, 70s and 80s found fairly consistent results. The average performance rating was between 76% and 81% of the NPC. Discussing average performance ratings is useful when thinking about the energy wasted within the irrigation industry as a whole. But individual producers need to identify which specific pumping plants are highly efficient, average or poor. The primary purpose of this paper is to demonstrate how a producer can use existing records to identify pumping plants that should be tested by a professional so those with low performance ratings can be adjusted, repaired or replaced with a better design.

This involves a five step calculation procedure.

Step 1. Calculate the water horsepower output of the pumping plant.

whp-h = acre-inches[f] pumped x total head (ft) / 8.75 whp-h / ac-in x ft

Where:

- whp-h = water horsepower hours
- acre-inches = volume of water necessary to cover an acre one inch deep. 27,154 gallons.
- total head (ft) = lift (ft) + system pressure (ft)
    - lift = distance (feet) from the water level inside the well casing to the discharge head while pumping.
    - system pressure (ft) = psi x 2.31 ft/psi

Step 2. Performance = whp-h / fuel used for the test period

Step 3. Performance rating = (Performance / NPC for the energy source) x 100%

Step 4. Potential fuel savings = ((100% - %NPC) / 100) x fuel used for the test period

Step 5. Potential Dollar Savings = Fuel savings x Fuel price

[f] Conversion to acre-inches

- If the water meter totalizer registers in gallons, divide gallons by 27,154.
- If the water meter totalizer registers in acre-feet, multiply acre-feet by 12.
- If the water meter totalizer registers in cubic feet, divide cubic feet by 3,630.

Example:

- Test period: Entire irrigation season
- System: Center pivot sprinkler system with a diesel engine.
- Pumping water level: 140 feet
- Pressure at the discharge head: 40 psi
- Ac-in of water pumped (from water meter)[f]: 1,415
- Total fuel used for test period = 3,571 gallons of diesel
- Diesel fuel price: $2.20 /gallon

Step 1. whp-h = acre-inches[f] pumped x total head (ft) / 8.75
= 1415 x (140 + (40 x 2.31)) / 8.75
= 1415 x (140 + 92.4) / 8.75
= 1415 x (232.4) / 8.75
= 37,518 whp-h

Step 2. Performance = whp-h for the test period / fuel used for the test period
= 37,518 whp-h / 3,571 gallons
= 10.5 whp-h / gallon

Step 3. Performance rating = (Performance/ NPC for the energy source) x 100%
= (10.5 whp-h / gallon / 12.5 whp-h / gallon of diesel) x 100%
= 84%

Step 4. Potential fuel savings = ((100% - %NPC) / 100) x fuel used for the test period
= ((100% - 84%) /100) x 3,571 gallons of diesel
= 0.16 x 3,571 gallons
= 571 gallons

Step 5. Potential Dollar Savings = Fuel savings x Fuel price
= 571 gallons x $2.20 per gallon
= $1256.20

For those with a computer and access to the internet, the author has created an Excel workbook to simplify the calculations. Results include: performance, performance rating, potential energy savings and potential dollar savings using records. The program can be run on-line in most popular internet browsers or it can be downloaded to the user's computer and opened in Excel.

The link to this workbook can be found on the Irrigation page of University of Nebraska in Lancaster County website http://lancaster.unl.edu/ag/crops/irrigate.shtml Click on Long Term Pump.xls as shown in the screen capture on the next page.
The workbook has a fill in the blanks worksheet plus three examples.

The Diesel Example worksheet is represented by the lower screen capture. Notice the tabs at the bottom of the worksheet. Click on the tabs to see examples or to open and use the Worksheet to calculate the performance of your pumping plants.

accompanies the Crop Watch articles above. Microsoft Internet Explorer TM is able to open the file on-line, if desired. To download the Excel worksheet to your computer, **right click** on the link below and select **"save as"** to save the file to the folder of your choice on your computer. To use the file, start Excel, browse to the file and open it normally.

- Long_Term_Pump.xls Excel worksheet to calculate long-term pumping plant performance from your records

Web Site Feedback Form

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Cost of Owning and Operating an Irrigation System

1				
2	**Estimate Pumping Plant Performance Rating and Potential Energy Savings**			
3	**From Your Records**			
4	Developed by Tom Dorn and Randy Pryor, UNL Extension Educators 1/20/2006		Revised 1/16/2007	
5				
6	**Note: This is an example worksheet and cannot be edited. Click on Worksheet tab at bottom to enter your values.**			
7				
8	**Step 1. Select energy type:**	**Energy**	**NPC**	**Energy Units**
9	**Choices: Diesel, Electricity, Gasoline,Nat Gas, NG Therm, or Propane**	Diesel	**12.5**	**Gallons**
10				
11	**Step 2. Input energy price per unit in cell E11**		Energy $/unit	$2.2000
12				
13				
14		**Water Meter Readings**		
15	**Step 3. Select Water meter totalizer units**	**Units**	**Beginning**	**Ending**
16	Choices: **Gallons, Ac-In**, **Ac-ft** or **No meter**	Acre-In	27123.0	28623.0
17	**Step 4. Type beginning reading in D16 and ending reading in E16**			
18				
19				
20				
21				
22				
23	**Please input the following:**			
24	**Step 5. Pumping water level**	160	**Feet**	
25	**Step 6. Pressure at the discharge head**	45	**PSI**	
26	**Step 7. Total fuel used for test period**	4700	**Gallons**	
27				
28				
29	**Results**			
30	**Ac-In of water pumped (from water meter readings)**	**1500.0**	**ac-inches**	
31	**Water horsepower hours (whp-h) for test period**	**45248.6**	**whp-h**	
32	**Estimated performance of this pumping plant**	**9.63**	**whp-h per unit of fuel**	
33	**Performance rating, % of the NPC**	**77.0**	**Percent**	
34				
35	**Potential Fuel Savings over test period**	**1080**	**Gallons**	
36				
37	**Potential Fuel Cost Savings over test period**	**$2,376**		
38				
39	Based on 75% pump efficiency			
40	**Nat Gas** is priced $/MCF assumed 925 BTU/cubic foot, (925,000 BTU/MCF)			
41	**NG Therm** is priced by the Therm (100,000 BTU)			

Worksheet | Diesel Example | Electric Example | No Water Meter