Using Your Records to Locate Inefficient Pumping Plants

Thomas W. Dorn Extension Educator University of Nebraska-Lincoln in Lancaster County 444 Cherrycreek Road, Lincoln, NE 68528 Voice: 402-441-7180 Fax: 402-441-7148 Email: tdorn1@unl.edu

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.

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

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

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 = $((100\% \%NPC) / 100) \times$ fuel used for the test period = $((100\% - 84\%) / 100) \times 3,571$ 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 <u>http://lancaster.unl.edu/ag/crops/irrigate.shtml</u> Click on <u>Long Term Pump.xls</u> 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

WED SIDE FEEDDACK FUTIT

Contact Information

Tom Dorn, Extension Educator tdorn1@unl.edu University of Nebraska-Lincoln in Lancaster County, 444 Cherrycreek Road, Suite A, Lincoln, NE 6852B lancaster@unl.edu | 402-441-7180

Cost of Owning and Operating an Irrigation System

2 Estimate Pumping Plant Performance Rating and Potential Energy Savings 3 From Your Records 4 Developed by Tam Dorn and Randy Prov, UNL Extension Educators 120/2006 Revised 1/16/2007 6 Note: This is an example worksheet and cannot be adited. Click on Worksheet tab at hottom to enter your values. 7 Energy NPC Energy Units 8 Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Dissel, Bectricty, Gasoline,Jkm Gas, NG Therm, or Propand Dised 12.5 Gallons 10 Step 2. Input energy price per unit in cell Ef1 Energy \$/unit \$2,2000 22000 12 Valuer Meter Readings Ending Ending 16 Choices: Gallone, Ac-In, Ac-In or No meter Acre-In 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16 Image: Step 5. Image: Step 5. Image: Step 5. Step 5. Step 5. Step 6. Pressure at the discharge head 455 PS1 28 Step 6. Pressure at the discharge head 450 PS1 Image: Step 5. Image: Step 7. Image: Step	1									
3 From Your Records 4 Developed by Tam Dorn and Randy Phyor, UNL Extension Educators 1/20/2006 Revised 1/18/2007 6 Note: This is an example workshoot and cannot be adhot. Click on Workshoot tab at bottom to enter your values. 7 Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Diseal, Beachicky, Gasoline, Jax Gas, No Therm, or Propand Cined 12.5 Gallons 10 Step 2. Input energy price per unit in cell Ef1 Energy Vinit \$22,2000 12 Step 3. Select Water meter totalizer units Units Beginning Ending 14 Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallone, Ac-In, Ac-It Dr No meter Arrein 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16 Image: Step 5. Image: Step 5. Step 6. Pressure at the discharge head 45 PS1 23 Please input the following: Image: Step 5. Ac-In of water pumped (from water meter readings) 1800.0 ac-In cless ac-In cless 24 Step 5. Pumping water level 160 Feet Image: Step 5. Step 7. Total fuel us	2	2 Estimate Pumping Plant Performance Rating and Potential Energy Savings								
4 Developed by Tom Dorn and Randy Pyor, UNL Extension Educators 1/20/2006 Revised 1/18/2007 6 Note: This is an example workshoot and cannot be edited. Click on Workshoot tab at bettom to entry your values. 7 Energy NPC Energy Units 8 Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Diseal, Bectricity, Gasolheaka Gas, NG Therm, or Propand Clicked 12.5 Gallons 10 Choices: Diseal, Bectricity, Gasolheaka Gas, NG Therm, or Propand Clicked 12.5 Gallons 11 Step 2. Input energy price per unit in call E11 Energy \$/unit \$2.2000 12 Choices: Gallons, Ac-In, Ac-At or No meter Acre in 212.30 28623.0 16 Choices: Gallons, Ac-In, Ac-At or No meter Acre in 212.30 28623.0 17 Step 1. Type beginning reading in D16 and ending reading in E16 Image: Step 1. Image: Step 1. Image: Step 1. 212.30 28623.0 18 Step 5. Purpping water level 1600 Feet Image: Step 1. Image: Step 1. Image: Step 1. Image: Step 1. 21 Image: Step 2. Pressure at the discharge head 45 PS1 Image: Step 1.	Э	From Your Records								
5 Note: This is an example work sheet and cannot be edited. Click on Worksheet tab at bottom to enter your values. 6 Note: This is an example work sheet and cannot be edited. Click on Worksheet tab at bottom to enter your values. 7 Energy NPC Energy Units 8 Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Dissel, Biotricky, Gasoline,Mar Gas, NG Therm, or Propane Dissed 12.5 Gallons 10 Energy NPC Energy \$/unit \$2,2000 11 Step 2. Input energy price per unit in cell E11 Energy \$/unit \$2,2000 12 Units Beginning Ending 14 Choices: Gallone, Ac-in, Ac-fr or No meter Acre-in 27123.0 28623.0 15 Step 1. Type beginning reading in D16 and ending reading in E16 Image: Step 1 Image: St	4	Developed by Tom Dorn and Randy Pryor, UNL Extension Educators 1	1/20/2006	Revised 1/16/2007						
6 Nete: This is an oxample workshoot and cannot be edited. Click on Workshoot tab at bottom to enter your values. 7 Image: Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Dissel, Beetricky, Gasoline,Ker Gas, NG Therm, or Propane Cread 12.5 Gallons 10 Step 2. Input energy price per unit in cell Ef1 Energy Winkt \$2.2000 11 Step 3. Select Water meter totalizer units Units Beginning Ending 14 Water Meter Readings Ending Ending 14 Water Meter Readings Ending 27123.0 28623.0 15 Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallone, Ac-In, Ac-In or No meter Acre>in 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16 Image: Second Se	5									
7 Image: Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Dissel, Bectricky, Gasoline Jar Gas, NG Therm, or Propane III. III. III. III. Gallons 11 Step 2. Input energy pilce per unit in cell Ef1 Energy 4/unit \$2,2000 12 Vater Meter Readings Energy III. \$2,2000 13 Units Beginning Ending 14 Water Meter Readings Ending 15 Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallons, Ac-In, Ac-fr or No meter Acre in 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16	6	Note: This is an example worksheet and cannot be edited. Click on V	Worksheet tab at	bottom to enter y	our values.					
8 Step 1. Select energy type: Energy NPC Energy Units 9 Choices: Diesel, Electricity, Gasoline,Mar Gas, NG Therm, or Propane Image: Choices: Choice: Choices: Choi	7									
9 Choices: Diesel, Electricity, Gasoliho,Mar Gas, NG Therm, or Propand Diesel ▼ 12.5 Gallons 10 Step 2. Input energy price per unit in cell E11 Energy \$/unit \$2.000 12	8	Step 1. Select energy type:	Energy	NPC	Energy Units					
10 Step 2. Input energy price per unit in cell E11 Energy \$/unit \$2.000 12 Water Meter Readings Energy \$/unit \$2.000 14 Water Meter Readings Energy \$/unit \$2.000 14 Water Meter Readings Ending 16 Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallons, A.c.in, A.c.ft or No meter Acre-in ✓ 27(23.0) 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16 ✓ ✓ ✓ 18 ✓ ✓ ✓ ✓ ✓ ✓ 20 ✓ <td< td=""><td>9</td><td>Choices: Diesel, Electricity, Gasoline,Nat Gas, NG Therm, or Propane</td><td>Diesel 🔻</td><td>12.5</td><td>Gallons</td></td<>	9	Choices: Diesel, Electricity, Gasoline,Nat Gas, NG Therm, or Propane	Diesel 🔻	12.5	Gallons					
11 Step 2. Input energy price per unit in cell E11 Energy \$'unit \$2.2000 12	10									
12 Image: second s	11	Step 2. Input energy price per unit in cell E11		Energy \$/unit	\$2.2000					
13 Water Meter Readings 14 Water Meter Readings 15 Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallons, Ac-In, Ac-fi or No meter Acre-in ✓ 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16 ✓ 2012 2012 2012 18 ✓ ✓ 27123.0 28623.0 28623.0 18 ✓ ✓ 27123.0 28623.0 18 ✓ ✓ 27123.0 28623.0 19 ✓ ✓ 27123.0 28623.0 10 ✓ ✓ 27123.0 28623.0 10 ✓ ✓ 27123.0 28623.0 11 ✓ ✓ ✓ ✓ ✓ 27123.0 28623.0 12 ✓ ✓ ✓ ✓ ✓ ✓ ✓ 12 ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ 13 Ølease input the following: ✓ ✓ <	12									
Initial Water Meter Readings Initial Step 3. Select Water meter totalizer units Units Beginning Ending Initial Choicse: Gallons, Ac-In, Ac-In or No meter Acre-In 27123.0 28623.0 Initial Step 4. Type beginning reading in D16 and ending reading in E16 2 2 2 Initial Initial Initial Initial Initial 2 2 2 2 Initial Initial Initial Initial Initial Initial 2 <th< td=""><td>13</td><td></td><td></td><td></td><td></td></th<>	13									
Step 3. Select Water meter totalizer units Units Beginning Ending 16 Choices: Gallons, Ac-In, Ac-fr or No meter Acre-In 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16	14		Wat		er Meter Readings					
16 Choices: Gallons, Ac-In, Ac-fr or No meter Acre-In ✓ 27123.0 28623.0 17 Step 4. Type beginning reading in D16 and ending reading in E16	15	Step 3. Select Water meter totalizer units	Units	Beginning	Ending					
17 Step 4. Type beginning reading in D16 and ending reading in E16	16	Choices: Gallons, Ac-In, Ac-ft or No meter	Acre-In 📃 💌	27123.0	28623.0					
18	17	Step 4. Type beginning reading in D16 and ending reading	in E16							
19 Image: step in the im	18									
20 Image: speed of the set of	19									
21	20									
22 Please input the following: Image: state input the following: 23 Please input the following: Image: state 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 Image: step 7. Total fuel used for test period 4700 Gallons 28 Image: step 7. Total fuel used for test period 4700 Gallons 29 Results Image: step 7. Image: step 7. 30 Ac-In of water pumped (from water meter readings) 1600.0 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 Image: step 7. Image: step 7. Image: step 7. 35 Potential Fuel Cost Savings over test period 1080 Gallons 36 Image: step 7. Image: step 7. Image: step 7. 39	21									
23 Please input the following: 160 Feet 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	22									
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	23	Please input the following:								
25 Step 6. Pressure at the discharge head 45 PSI 26 Step 7. Total fuel used for test period 4700 Gallons 27 Control fuel used for test period 4700 Gallons 28 Results Control fuel used for test period ac-inches 30 Ac-in of water pumped (from water meter readings) 1600.0 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 Control fuel 1080 Gallons 35 Potential Fuel Savings over test period 1080 Gallons 36 Potential Fuel Cost Savings over test period \$2,376 Control fuel 38 Sased on 75% pump efficiency Sased on 75% pump efficiency Sased on 75% pump efficiency 40 Nat Gas is priced \$/MCF assumed 925 EFTU/cubic fool, (\$25,000 ETU/MCF) Sased on 75% Sased on 75% 41 N Worksheet), Otesel Example / Eastric Example / Not water Mater / Sased on 75% Sased on 75%	24	Step 5. Pumping water level	160	Feet						
26 Step 7. Total fuel used for test period 4700 Gallons 27	25	Step 6. Pressure at the discharge head	45	PSI						
27	26	Step 7. Total fuel used for test period	4700	Gallons						
28 Results 29 Results 30 Ac-In of water pumped (from water meter readings) 1600.0 ac-inches 31 Water horsepower hours (whp-h) for test period 46248.6 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 Potential Fuel Savings over test period 1080 Galions 36 Potential Fuel Cost Savings over test period 1080 Galions 38 Sased on 75% pump efficiency Image: Saving State Stat	27									
23 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	28									
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	29	Results	<u></u>							
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	30	Ac-in of water pumped (from water meter readings)	1500.0	ac-Inches						
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	31	Water horsepower hours (whp-h) for test period	45248.6	whp-h						
33 Performance rating, % of the NPC 77.0 Percent 34	32	Estimated performance of this pumping plant	9.63	9.63 whp-h per unit of fuel						
34	33	Performance rating, % of the NPC	77.0	77.0 Percent						
35 Potential Fuel Savings over test period 1080 Galions 36	34									
36 37 Potential Fuel Cost Savings over test period \$2,376 38 38 39 Based on 75% pump efficiency 40 Hat Gas is priced \$/MCF assumed 925 ETU/cubic foot, (925,000 ETU/MCF) 41 41 HG Therm is priced by the Therm (100,000 BTU) 41 42 H\ Worksheet), Otesel Example (Electric Example (The Water Mater /	35	Potential Fuel Savings over test period	1080	1080 Gallons						
37 Potential Fuel Cost Savings over test period \$2,376 38	36									
38 39 Based on 75% pump efficiency 40 Hat Gas is priced \$/MCF assumed 925 ETU/cubic foot, (925,000 ETU/MCF) 41 HG Therm is priced by the Therm (100,000 BTU) H ⁴ + M Worksheet), Otesel Example (Eachtric Example (The Water Mater /	37	Potential Fuel Cost Savings over test period	\$2,376							
39 Based on 75% pump efficiency 40 Nat Gas is priced \$/MCF assumed 925 ETU/cubic foot, (925,000 ETU/MCF) 41 NG Therm is priced by the Therm (100,000 BTU) N ² 4 + N Worksheet), Diesel Example (Eachtic Example (No Water Mater /	38									
40 Hat Gas is priced \$/MCF assumed 925 BTU/cubic foot, (925,000 BTU/MCF) 41 HG Therm is priced by the Therm (100,000 BTU) H 4 + N Worksheet , Diesel Example , Elactric Example , No Water Mater /	39	Based on 75% pump efficiency								
41 ING Therm is priced by the Therm (100,000 BTU) 41 4 42 4 42 4 43 4 44 4 44 4 44 4 44 4 45 4 44 4 44 4 44 4 44 4 44 4 44 <td>40</td> <td colspan="4">40 Hat Gas is priced \$/MCF assumed 925 BTU/cubic foot, (925,000 BTU/MCF)</td>	40	40 Hat Gas is priced \$/MCF assumed 925 BTU/cubic foot, (925,000 BTU/MCF)								
N 4 + N Worksheet Diesel Example / Elatoric Example / No Water Mater /	41	NG Therm is priced by the Therm (100,000 BTU)								
	H 4									