TECHNICAL ADVISORY

Customer Energy Efficiency Program

Pump Efficiency Tests from the Advanced Pumping Efficiency Program

The Advanced Pumping Efficiency Program (APEP) provides subsidized pump efficiency tests (subject to available funding). If you are thinking about retrofitting an inefficient pump, APEP may also be able to provide a cash incentive to help you make that decision.

To obtain a subsidized pump test under the Advanced Pumping Efficiency Program you must use one of our participating pump test companies. Please call or log on to our web site at **www.pumpefficiency.org** for a current list of these companies. A full explanation of how to obtain an APEP-sponsored test is contained at the end of this Advisory.

New pumps should be tested to provide a baseline for later performance measurements.

Pumps become inefficient for one of two reasons:

1. They are physically worn.
2. The pump is not matched to the current required operating conditions. An example of this would be where a water table has dropped substantially over time, increasing the total lift above the original engineering specifications.

Periodic pump efficiency tests can alert you when a pump is becoming, or already is, inefficient. It provides vital information that can help you decide when to retrofit or repair an inefficient pump. In conjunction with the original pump performance curve and specifications, it can also indicate which of the reasons above are to blame. This Technical Advisory explains the pump efficiency test and describes what is contained in the report.

WHAT IS A PUMP EFFICIENCY TEST?

A pump test measures important aspects of the pump's operation including flow, discharge pressure, well lift (if applicable), and power use. The end result of a pump test is an estimate of the overall efficiency of your pump and the cost of running it under the conditions of the test. The test may also give an indication of water well performance.

WHO DOES THE PUMP TESTING?

Pump tests may be available from:

- Public utilities - using either their own employees or contract testers.
- Pump dealers - using their own employees or contract testers.
- Independent pump test companies - many of these testers have a public utility background.

WHAT DOES A PUMP TESTER MEASURE?

The tester measures at least four variables:

1. Water flow rate.
2. Pumping lift for a well or inlet pressure for a booster pump.
3. Pump discharge pressure.
4. Energy input to the pumping plant.

Calculations are performed with the flow, lift, and discharge pressure measurements and the results are compared to the energy input to the pumping plant. A sample pump test report and an explanation of what it measures and calculates is shown in **Figure 1.**

WHY SHOULD I TEST MY PUMP?

Regular pump testing can identify problems before a breakdown occurs or energy bills climb. This allows you to perform an objective economic analysis to identify when it can be profitable to invest in a retrofit. On a new pump, a test will establish a baseline of performance and verify that equipment is operating as designed. A typical analysis of pumping costs derived from a test, along with explanations of the variables used in the calculations is shown in **Figure 2.**

HOW DO I PREPARE FOR A PUMP TEST?

Check with your pump tester about how to prepare for a pump test. Some testers use flow measurement equipment that requires an access hole in the pump discharge pipe. Generally, the pump needs to be off in order to cut the hole and insert the device. Some measurement devices do not require this provision. The pump must be running during the test and there must be some place for the pumped water to go. If the pump is in a water well, the tester may need to run the pump as long as 30-45 minutes to stabilize the pumping water level.

The pump tester will also need information regarding the pump's management and design in order to do a complete cost analysis. Key information will include:

- Annual acre-feet pumped (or hours of operation).
- Average cost of energy ($ per kWh or $ per therm) for the year.
- Intended operating condition.
- Required flow rate.
- Required discharge pressure of the pump.

If a water well is running when the tester arrives, the tester will want to shut it off after the test measurements are taken in order to measure the "recovered water level" of the well. (Generally, this shut-off time is at least 15 minutes.) This valuable information indicates current well performance.

INTERPRETING THE PUMP TEST REPORT

A test report from an APEP-approved tester will have two basic sections, the Pump Test Report **(Figure 1)** and the Pumping Cost Analysis **(Figure 2).**

TO EXPLAIN THE NUMBERS IN FIGURE 1:

1. **Pumping Water Level (ft) -** Where the water level in the well stabilizes under constant pumping conditions.
2. **Standing Water Level (ft) -** The water level in the well when a pump has not been running.
3. **Draw Down (ft) -** The difference between the pumping water level and the standing water level.
4. **Recovered Water Level (ft) -** The water level in the water well 15 minutes after shutting the pump off (check with the tester for how much time was allowed before making this measurement).
5. **Discharge Pressure at Gauge (psi) -** The pressure on the outlet side of the pump in pounds-per-square-inch (1 psi = 2.31 feet of water head).
6. **Total Lift (ft) -** Includes the pumping water level, discharge pressure, and any gauge corrections. There are also minor losses due to inlet restrictions, column friction, and fittings. These minor losses are not measured during the test.
7. **Flow Velocity (fps) -** How fast the water is moving in the discharge pipe. It should be 1 foot per second or faster to ensure an accurate test.
8. **Measured Flow Rate (gpm) -** The flow rate measured in gallons per minute by the tester.
9. **Customer Flow Rate (gpm) -** The flow rate measured with the customer's flow meter (if one is present).
10. **Well Specific Capacity (gpm/ft draw) -** The measured flow rate divided by the draw down (line 8 divided by line 3). It is a measure of well performance, not pump performance.
11. **Acre-Feet per 24 Hours -** The number of acre-feet pumped in 24 hours at the measured flow rate. One acre-foot of water is about equal to 325,900 gallons of water.
12. **Cubic Feet per Second (cfs) -** The measured flow rate expressed as cubic feet of water per second.
13. **Horsepower input to Motor-** The horsepower input to the motor read at the utility meter.
14. **Percent of Rated Motor Load -** The estimated horsepower output of the motor divided by the name plate horsepower. If this is not between 80% and 115% it is an indication that the motor is not matched to the pumping condition.
15. **Kilowatt Input to Motor -** The power input to the motor in terms of kilowatts. One horsepower is equal to 0.746 kilowatts.
16. **Kilowatt-hours per Acre-Foot -** The amount of kilowatt-hours required to pump an acre-foot of water at the operating condition measured.
17. **Cost to Pump an Acre-Foot -** Kilowatt-hours per acre-foot multiplied by the base cost per kWh (line 19).
18. **Energy Cost ($/hour) -** The cost per hour to run the pump at the base cost per kWh (line 19).

Pump Test Report Sample

Run	1	2
1. Pumping Water Level (ft):	175	171
2. Standing Water Level (ft):	155	155
3. Draw Down (ft):	20	16
4. Recovered Water Level (ft):	155	155
5. Discharge Pressure at Gauge (psi):	5	15
6. Total Lift (ft):	187	206
7. Flow Velocity (fps):	5.3	4.3
8. Measured Flow Rate (gpm):	**1,350**	**1,100**
9. Customer Flow Rate (gpm):	0	0
10. Specific Capacity (gpm/ft draw):	67.5	68.5
11. Acre Feet per 24 Hr: **Million Gallons per 24 Hr:**	6.0 1.944	4.86 1.584
12. Cubic Feet per Second (cfs):	3.0	2.4
13. Horsepower Input to Motor	161	168
14. Percent of Rated Motor Load	117	122
15. Kilowatt Input to Motor	120	125
16. Kilowatt Hours per Acre-Foot	482	620
17. Cost to Pump an Acre-Foot	$65.03	$83.70
18. Energy Cost ($/Hour)	$16.16	$16.87
19. Base Cost per kWh:	$0.135	$0.135
20. Nameplate RPM:	1780	17809
21. RPM at Pump Shaft:	0	0
22. Overall Pumping Efficiency (%):	**39**	**34**

Figure 1 – Measurements and Test Results Section of a Pump Efficiency Test Report (two conditions tested)

Tester's Remarks
All results are based on conditions during the time of the test. If these conditions vary from the normal operation of your pump, the results shown may not describe the pump's normal performance.

Pumping Cost Analysis Sample

* Denotes a value that was assumed or provided by customer.	Measured Pump Condition	Assumed After Retrofit	Notes
1. Overall Pumping Efficiency:	39%	65%	
2. Nameplate Horsepower:	125.0 HP	125.0 HP	
3. Motor Efficiency:	91%	91%	
4. Actual Motor Input Horsepower:	160.5 HP	134.3 HP	
5. Motor Loaded at:	117%	98%	
6. Flow Rate (gpm):	1,350 gpm	1,800 gpm	
7. Pumping Level (ft):	175 ft	182 ft	
8. Discharge Pressure (psi):	5 psi	5 psi	
9. Total Dynamic Head (feet):	187 ft	194 ft	Rounded TDH = line 7. + (2.31 x line 8.)
10. Acre-feet Pumped per year:	248.56 AF/Yr*	248.56 AF/Yr*	Same AF/Yr AFTER
11. Average Cost per kWh:	$0.135/kWh*	$0.135/kWh*	Same $/kWh AFTER
			Estimated Savings from Retrofit
12. Estimated Total kWh per Year:	122,043 kWh/Yr	75,811 kWh/Yr	46,232 kWh/Yr
13. Hours of Operation per year:	1,000 Hr/Yr*	750 Hr/Yr	250 Hr/Yr
14. Kilowatt-hours per Acre-Foot:	491 kWh/AF	305 kWh/AF	186 kWh/AF
15. Average Cost Per Acre-Foot:	$66.29/AF	$41.18/AF	$25.11/AF = 37.9%

- Estimated savings = $25.11/AF = 37.9% of energy costs
- If pumping 248.56 AF/year this equals about $6,241 annual savings

Figure 2 – Example Pumping Cost Analysis Section of an APEP Test Report - Using Run 1 from Figure 1 as the Measured Pump Condition (note that many numbers are rounded during calculations)

19. **Base Cost per kWh** - The average cost of a kilowatt-hour for this account.
20. **Name Plate RPM -** The rated speed of the motor.
21. **Measured RPM at Pump Shaft -** The actual rotational speed measured.
22. **Overall Pumping Efficiency (%) -** The power output of the pump (a function of the flow rate and total lift) divided by the input power.

The pumping cost analysis presented is only valid for the "assumed after retrofit" conditions and for the conditions measured during the test. One or more of the assumed variables resulting from a pump repair could be in error and the economics presented would be misleading. Use this section only as a guide to the magnitude of potential savings. Always consult with your pump service company and other available experts before making the decision to retrofit a pump.

If your pumping plant includes a very old motor, or one that has been rewound more than once, it may be a significant contributor to a low measured pumping efficiency.

TO EXPLAIN THE NUMBERS IN FIGURE 2:

1. **Overall Pumping Efficiency -** The improvement expected in overall pump efficiency after retrofit.
2. **Nameplate Horsepower -** This may change if the proposed retrofit includes a horsepower change.
3. **Motor Efficiency -** This may change if the proposed retrofit includes installing a premium high efficiency motor.
4. **Actual Motor Input Horsepower -** The power going through the electrical meter to the motor.
5. **Motor Loaded at -** Motor load based on the brake-horsepower output.
6. **Flow Rate -** Flow rate at current and assumed conditions.
7. **Pumping Level (or Input Water Level) -** This will change if this is a well and the flow changes.
8. **Discharge Pressure -** Discharge pressure at the current and assumed conditions.
9. **Total Dynamic Head -** The total of inlet pressure (or lift) and discharge pressure. There are also minor losses due to inlet restrictions, column friction, and fittings. These minor losses are not measured during the test.
10. **Acre-Feet Pumped per Year -** Annual water requirements will be assumed to be unchanged. You may want to discuss this assumption with the tester so that they match your expectations (or the expectations of your pump repair company).
11. **Average Cost per kWh -** The average cost per kilowatt-hour as stated by you, or estimated by the tester based on your pump size and rate schedule. The potential savings from a pump retrofit are directly related to this number. Check with your PG&E account representative if you are unsure of this value.
12. **Estimated Total kWh -** The total kilowatt-hours used annually if the hours of operation or total acre-feet pumped per year are known.
13. **Hours of Operation per Year -** Based on the current and assumed flow rate and the amount of water pumped per year.
14. **Kilowatt-Hours per Acre-Foot -** The kilowatt-hours required to pump an acre-foot through the system.
15. **Average Cost per Acre-Foot -** The average cost to pump an acre-foot of water through the system.

The estimated annual cost of energy noted at the bottom of this section may not include demand charges or other surcharges to run the pump. This will be zero if the annual hours of operation or annual acre-feet pumped are not known. If a total annual cost is not calculated you can use the average cost per acre-foot as an indicator to potential energy use and cost savings.

WHAT IS A MULTI-CONDITION PUMP TEST?

A pump can operate with a wide variety of flow and pressure outputs. A multi-condition test consists of making the required measurements at several different flow rates. This type of test is useful in situations where the pump design is unknown or where aquifer or discharge conditions have changed substantially. It may also lead to a decision to install a variable frequency drive (VFD). **Figure 1** gives an example of a multi-condition pump test.

CAN TWO PUMPS BE TESTED TOGETHER?

Pumping plants may be designed with a well pump to lift the water to the surface and a booster pump to supply pressure to the irrigation system. Typically, the well pump is tested first and then the well/booster combination is tested. The booster pump efficiency is determined by subtracting the inlet pressure into the booster from the discharge pressure and using the flow rate from the well. The electrical panel must be opened and power meter readings for each pump taken to determine input horsepower.

Accurate flow measurement is essential for both day-to-day management and the pump efficiency test. When installing a new pump make sure that your pump company includes discharge piping that will allow for an accurate flow measurement. Also, always consider installing a flow meter at the same time.

WHAT IS NEEDED FOR ACCURATE MEASUREMENT?

Water flow in a pipe can only be accurately determined if the location for flow measurement (known as the "test section") is free from turbulence. Ideally, the test section should be a run of straight pipe with lengths of eight to ten pipe diameters upstream and two to four pipe diameters downstream of the measurement point that are free of obstructions or turns (see the **Figure 3** below). In addition, access via a sounding tube or a factory-made hole in the discharge head may be needed to determine standing and pumping water levels in a well.

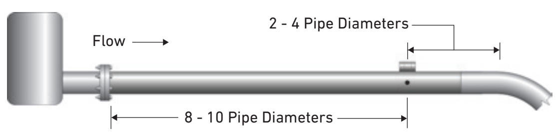

Figure 3 – Schematic of an Ideal Test Section

This schematic shows an ideal test section:

- Eight to ten pipe diameters upstream.
- Two to four pipe diameters downstream, clear of obstructions or turns. (For a 6-inch diameter pipe this would mean 48" to 60" upstream and 12" to 24" downstream clear.)

HOW DO I USE THE DATA FROM A PUMP TEST?

You should have a copy of your pump's original pump performance curve. Record the results of each pump test and compare them to that curve and to previous tests. Consult with your pump dealer to determine if a pump adjustment or repair will be profitable.

It is important to realize that the pump test results are only valid for the combination(s) of flow and total lift measured. You should try to ensure that the test conditions are as close as possible to typical operating conditions. For example, it is probably better to test a water well used for irrigation of annual crops during the growing season and not during the winter.

HOW OFTEN SHOULD I TEST MY PUMP?

A pump should be tested every one to three years depending on the annual usage and severity of operating conditions. For example, you might want to test a well that is pumping a lot of sand every year. On the other hand, a booster pump supplied by clean water, might only need to be tested once every two to three years.

The average pumping efficiency for all turbine pump tests in the APEP database is approximately 53%.

WHAT SHOULD BE MY PUMP'S OVERALL PUMPING EFFICIENCY (OPE)?

Overall pump efficiency can be generally characterized as follows:

- 60% and higher is excellent.
- 50% to 60% is good.
- 49% or less indicates a pump that may need a retrofit.

Pumps with submersible motors will usually run about 10% lower efficiency in each of the categories above. For example 50% or above would be considered excellent for a submersible pump. These are general characterizations. Always consult with your pump service company and other available experts before making the decision to retrofit/repair a pump.

HOW DO I GET A SUBSIDIZED PUMP EFFICIENCY TEST?

Subsidized pump efficiency tests are available (subject to available funding) from APEP-approved "participating pump test companies" for agricultural and municipal pumps. Residential, sewage and industrial process pumps are not eligible.

The test is subsidized. You are responsible for knowing how much the test company will charge you and whether you will have to provide funds in addition to the program subsidy.

Important restrictions include:

- Only one test is available every 23 months.
- The pump must be 25 horsepower or greater.
- In the case of a water well we must be able to measure the pumping water level.
- If the pump has been tested before by APEP testers with an overall efficiency less than 30% (6% for natural gas-powered pumps) and it has not been retrofitted, it is not eligible.
- Subsidized tests are not available for real estate transactions or to satisfy a mandate of any government or quasi-government agency.

To participate:

1. Contact the participating pump test company of your choice to arrange a test. Log on to the web site or call one of the Program offices listed below if you need assistance in locating a test company.
2. You will have to sign an Access Agreement before the test (granting legal access to your pump) and a Record of Test after the test (providing proof to the California Public Utilities Commission that the test was performed).
3. The tester will provide both you and the Program with a pump test report. You can discuss the results of the test with the pump test company and/or Program personnel.

Call to see how a pump efficiency test can provide you with the critical information required to make a decision about a pump retrofit.

APEP CAN HELP YOU MAINTAIN AN EFFICIENT PUMP

Log on to the web site at **www.pumpefficiency.org.** Here you will find summaries of all Program components, a calendar of upcoming events, application forms, phone numbers and e-mail addresses of the regional offices, and a knowledge-base to help you conserve energy and water. Or, call one of our offices:

- Northern California regional office – **1-559-260-6148**
- San Joaquin Valley (main office) – **1-800-845-6038** / fax to **1-559-278-2998**
- Central Coast regional office (San Mateo County to Ventura County) – **1-805-547-1130** / **1-805-709-4180**

Or, call your PG&E account representative.

These offerings are funded by California utility customers and administered by PG&E under the auspices of the California Public Utilities Commission
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