PUMP TESTING AND HYDRAULIC SERVICES MANUAL

Improving your overall pumping plant efficiency

SOUTHERN CALIFORNIA EDISON®

Energy for What's Ahead®

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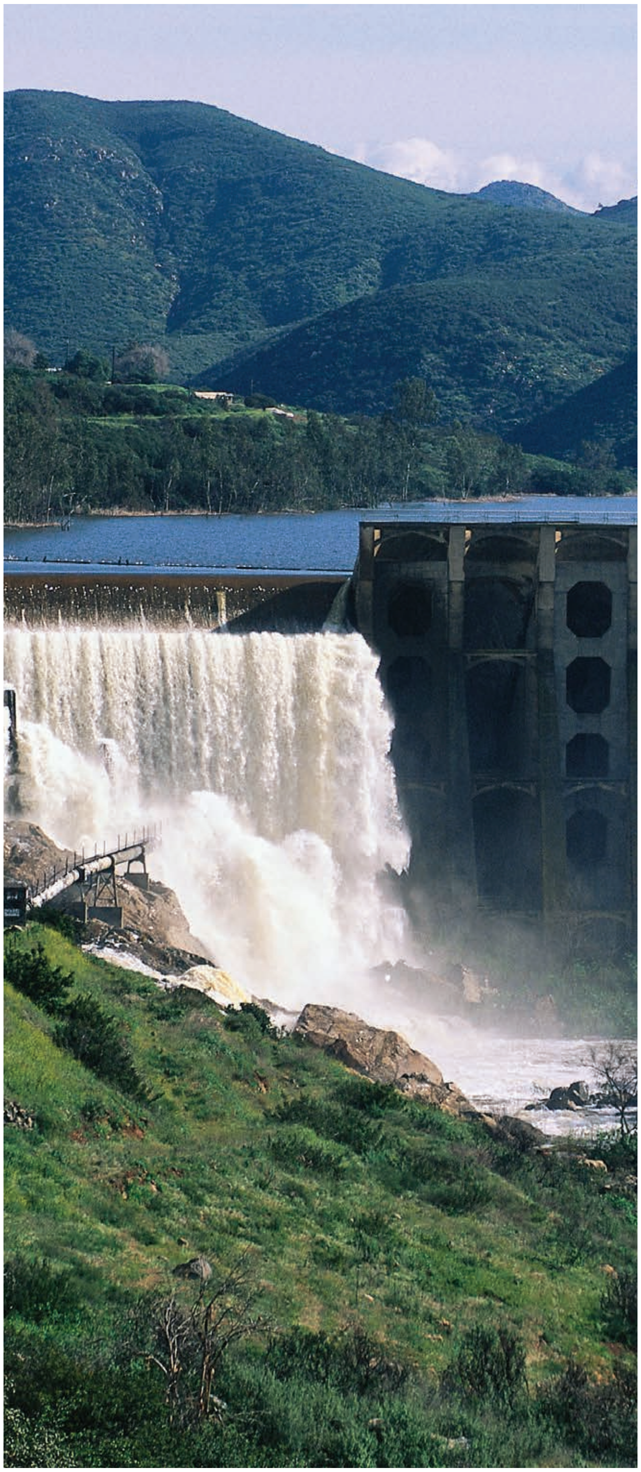
i.1 A RESOURCE FOR BUSINESS

At Southern California Edison (SCE), our Hydraulic Services Department has always had a strong dedication to safety and serving the customer. We do more than supply electrical energy; we also offer our customers the knowledge, insights and expertise from our more than 100 years of experience providing service to Californians.



Energy demands continue to increase resulting in strain on the energy available for every business and homeowner. It is our goal at SCE to support customers with tools and services that allow for more efficient energy use, money savings and ultimately the conservation of energy resources for all Californians.

Since 1911, we have provided pump testing for our clients. Employing state-of-the-art monitoring equipment, pursuing complex industrial pumps and systems — as well as large compressed air systems — our testing services provide information, advice and incentives to encourage businesses to take practical steps toward improved management of their energy usage and expenses.

It requires a significant amount of energy to power a water pumping system. If any pump is not working to specifications, or if the pumping requirements have changed, it's possible the plant could be using power inefficiently. Our pump testing services will provide you with information so you can assess your overall pumping performance. It will help identify current or potential problems, allowing you to take measures, if needed, to improve operations and lower your energy cost.

We want you to think of us not simply as your energy supplier, but also as an energy management resource providing information, answers or options. It is this century-long commitment that has helped turn SCE's first energy conservation program into a modern day, energy efficiency program.

Energy Efficiency Programs are funded by California utility ratepayers and are administered by Southern California Edison under the auspices of the California Public Utilities Commission.

WHAT THIS MANUAL COVERS

This booklet provides useful information for any business that uses pumps to irrigate property or deliver a water source. It is designed to **help you operate your pumping plants more efficiently**, thereby reducing energy costs. It can also guide you to the many resources and services from SCE and other entities that can help you save energy, money and improve your operations throughout the year.

Who Is This Manual for?

The information in this manual is valuable to any SCE client that operates a pumping plant to: irrigate crops, landscaping or turfgrass; supply water for domestic use; or supply water to an industrial process.

It is intended for any person desiring to know which questions to ask in order to operate, maintain, and manage an efficient pump system. It is also designed to effectively communicate with managers in the field who must make important decisions every day regarding energy use.

Please note that the information provided, such as the calculations and formulas regarding energy usage, is based on electrical energy measurements. Although the principles are the same, pumping operations that use natural gas or another energy source would not be able to use all of our formulas to measure pump performance.

What Is the Purpose of This Manual?

This booklet is primarily intended to help you understand the importance of pumping performance as it relates to managing energy use and lowering energy costs. We urge you to establish a regular pump test program if one is not already in place.

For those who are interested in assessing and measuring their system's overall pumping plant efficiency, this manual includes helpful electric energy-usage formulas, as well as the explanations of the factors used in them, to arrive at the key measurements.

From pump testing to energy efficiency incentives, we want you to know about the many resources available to you that can help you operate your pumping plant more efficiently. **We want to provide you with the tools that will help your business save time, money and energy.**

i.3 ADDITIONAL RESOURCES

Our Pump Testing and Hydraulic Services department offers a variety of services at no charge.

SCE Energy Education Centers

Our Energy Education Centers in Tulare and Irwindale provide energy management and energy-efficiency solutions through hands-on demonstrations of the latest state-of-the-art technologies as well as workshops, classes and interactive displays.

Energy Education Center – Tulare
4175 S. Laspina Street
Tulare, CA 93274
1-800-772-4822

Energy Education Center – Irwindale
6090 N. Irwindale Avenue
Irwindale, CA 91702
1-800-336-2822

Seminars

We offer a variety of seminars and classes at our Energy Education Centers. For a complete listing of upcoming classes, visit **sce.com/energycenters** or call:

Tulare	**1-800-772-4822**
Irwindale	**1-800-336-2822**

SCE's Customer Service

Business	**1-800-990-7788**
Agriculture	**1-800-634-9175**

Energy Efficiency Information and Incentives

SCE's Energy Efficiency Solutions
sce.com/solutions or call **1-800-736-4777**

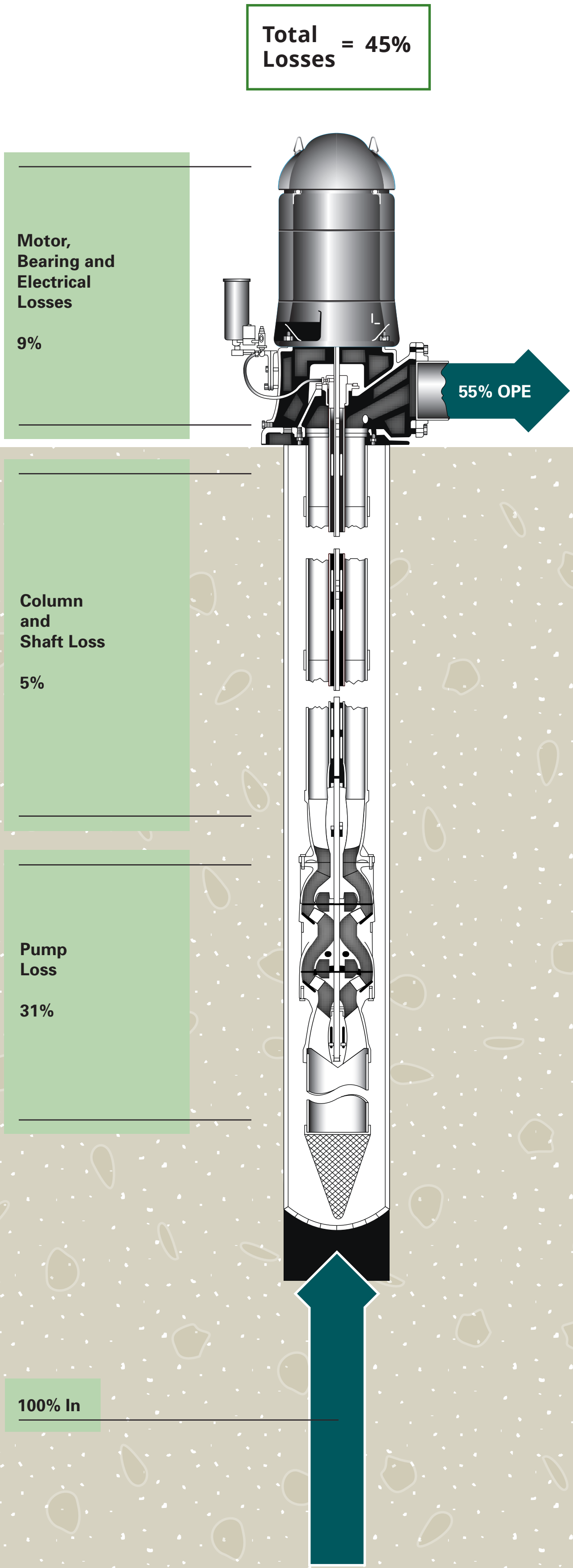
Websites

Hydraulic Institute
www.pumps.org

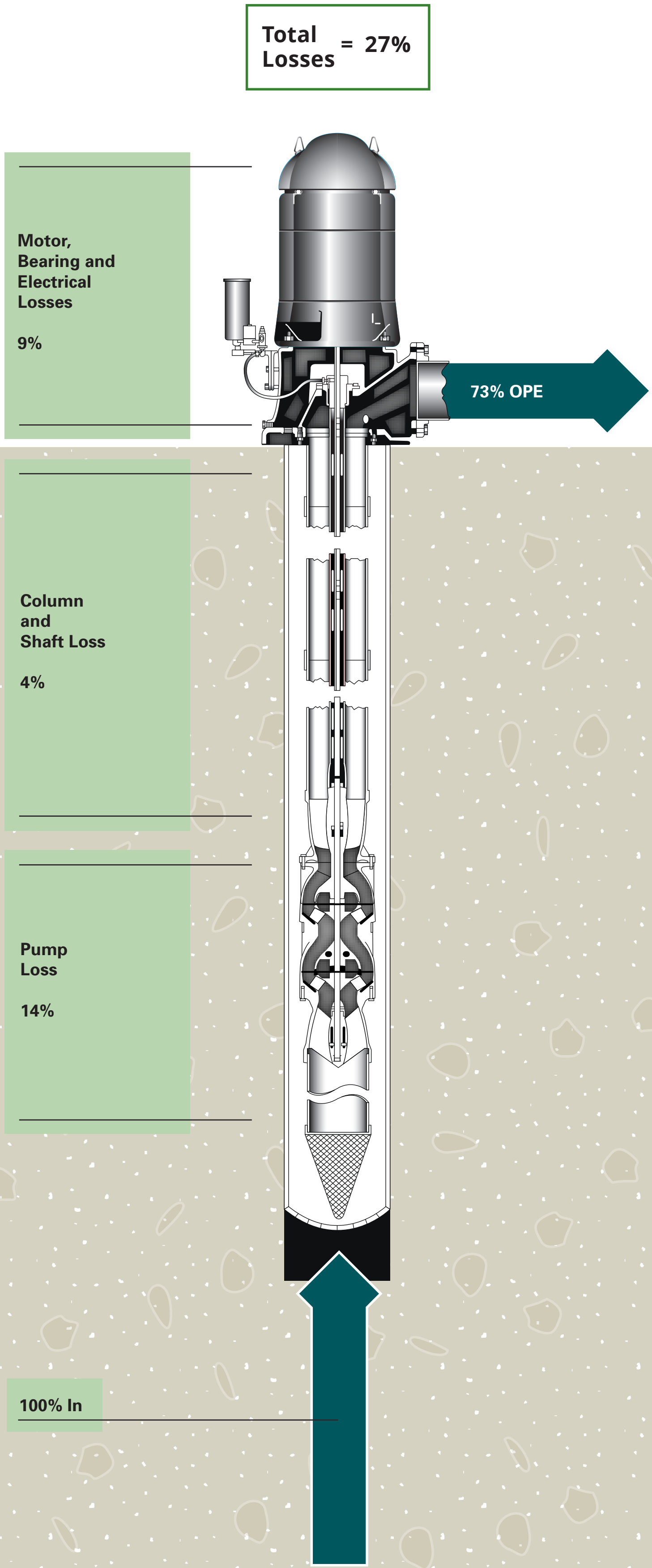
SCE for Agricultural Businesses
sce.com/water
sce.com/agriculture

Please see example on page 5.

Inefficient Plant



Efficient Plant



1.1 THE IMPORTANCE OF PUMP PERFORMANCE

A variety of factors can alter a pump's performance and cause energy and money to be wasted. As you know, **a pump does not have to be broken to be ineffective**; many "working" pumps are nonetheless working inefficiently. That is why it is critical to evaluate your pumping plant's operating efficiency routinely. A pump test from SCE can help you measure your plant's operating efficiency.

Pumping Plant Efficiency, Energy Demands, and Costs

For most agricultural clients and municipalities, the annual cost of energy represents a significant percentage of overall operating expenses. In fact, energy costs alone are sometimes as much as 60 to 70% of operating costs.

Additionally, for businesses that perform irrigation or that deliver water to other entities, a significant percentage of the cost of energy comes from the electric power required to pump the tremendous volume of water demanded daily and year-round by the business's operation. **Knowing your Overall Pumping Plant Efficiency (OPE) will help you manage your energy costs.**

The Cost of Poor Pump Performance

When one or more pumps are not operating efficiently, it may take more energy than necessary for the pump to perform as needed. That creates not only an inefficient use of a high-demand resource — it also represents a steady flow of your energy dollars going down the drain.

And consider that, even if a pump is operating properly, the pumping-system management itself may be inefficient. A pump test can help you to verify if the correct pump is in place or if the current pump you have could be used in a different way or at different times to conserve energy and save money.

Example: Inefficient vs. Efficient Pump

The table on the right provides an example of an inefficient pump versus an efficient pump. The example assumes that OPEs do not lessen or change over a 5-year period (or averaged the OPEs shown below over 5 years). Total Head does not change and water demand remains the same. The example also assumes $25,000 cost for improvement and shows an efficiency payback over a 5-year timeframe. **The calculation indicates a return on investment in approximately 2 years and an overall savings of $54,430 after 5 years.**

	Inefficient Pump	Efficient Pump	Savings
Overall Efficiency	55%	73%	
kWh/Acre Ft.	649	511	138
Acre Ft./Year	822	822	
Annual kWh	533,472	420,000	113,472
Cost per Year @ $.11/kWh	$74,686	$58,800	$15,886

5-Year Comparison: Inefficient vs. Efficient Overall Plant Efficiency

	Inefficient Plant	Efficient Plant			Payback
	Annual Cost @ 55% OPE	Annual Cost @ 73% OPE	Annual Operational Savings	Replacement Costs	Yearly Savings
Year 1	$74,686	$58,800	$15,886	$25,000	($9,114)
Year 2	$74,686	$58,800	$15,886		$6,772
Year 3	$74,686	$58,800	$15,886		**$15,886**
Year 4	$74,686	$58,800	$15,886		**$15,886**
Year 5	$74,686	$58,800	$15,886		**$15,886**
5 Year Totals:	$373,430	$294,000	$79,430	$25,000	**$54,430**

Pump Performance Factors

A pumping plant's operating efficiency is determined by a variety of factors:

- Type and size of pump
- Condition of the pump
- Pump speed
- Total Head or pump pressure
- Condition of the well
- Conversion of mechanical energy (pump) to water-energy (water flow), motor efficiency, power efficiency
- Transmission of water flow through pipes, fittings, valves, etc.

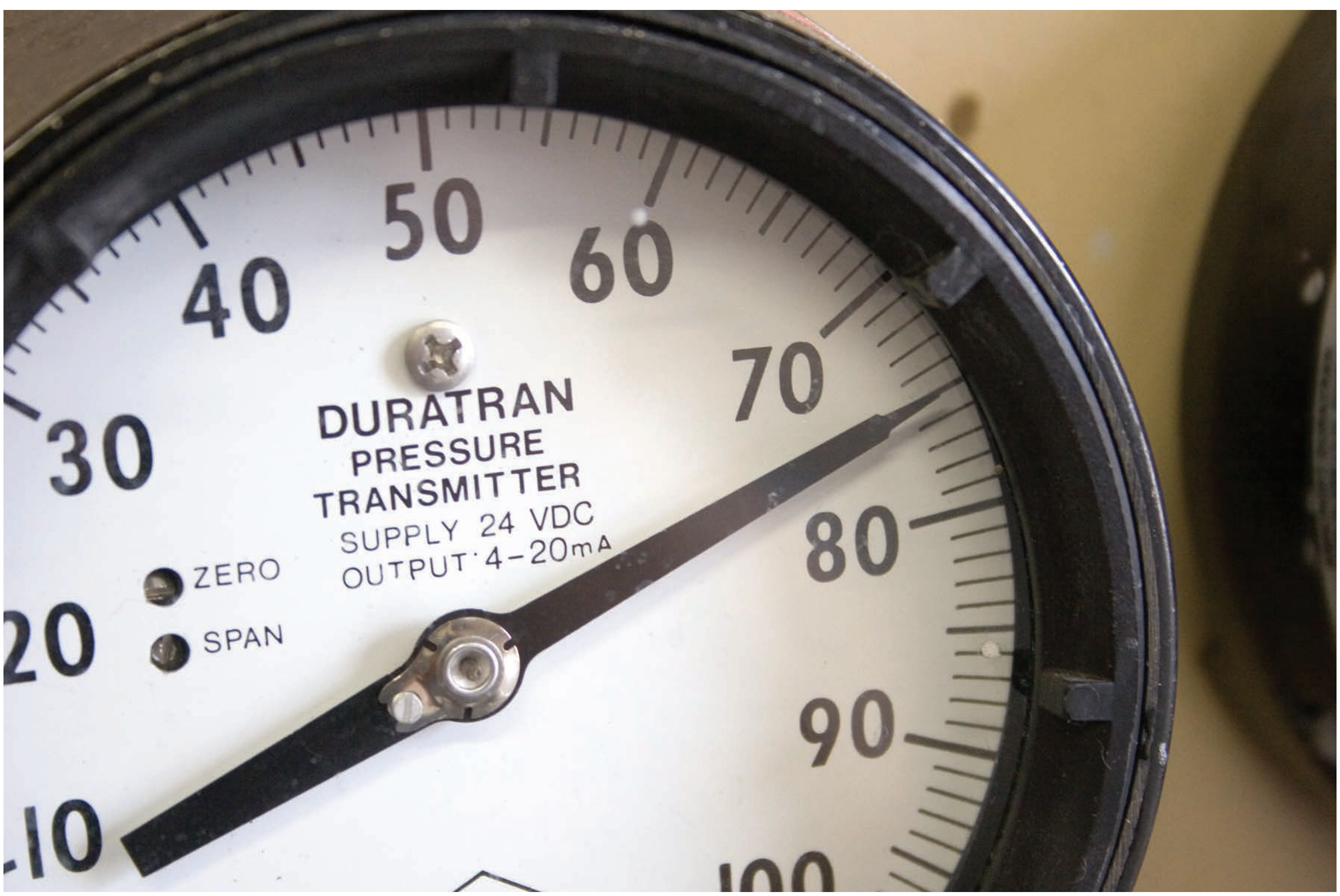
A well's performance will also generally degrade with time, due to a variety of causes:

- Well screen corrosion or encrustation of screen with various deposits reduce allowable flow openings into the well pump
- The well's gravel pack can plug up from fine materials such as silt
- Attempting to pump too much water by using too big a pump for the aquifer may result in low well-specific capacity

This subject is very important to your pumping costs. Consult with your pump dealer and/or well driller if the pump test history reveals significant reduction in well-specific capacity over time.

Preventive Steps, Proactive Measures

By taking **simple and ongoing steps to assess your pumping plant's performance**, you can make an informed and important business decision regarding pump repairs or replacements. Routine pump tests done at regular intervals, typically on a bi-annual basis, can help keep you avoid interruptions to your operations, help you manage energy costs, and **help you improve overall plant-operating efficiency**. See page 24, Predictive Maintenance Services for more information.



OPE RATING: OVERALL PUMPING PLANT EFFICIENCY

1.2

With ongoing measurements and data for your pumping system, **you can evaluate your pumping plant's efficiency and save energy and money**. Measuring your system's Overall Pumping Plant Efficiency (OPE) is a primary component of pumping system management and can aid in your decision making and affect your operating costs and performance.

The OPE is the relationship between the power consumed in kilowatts and the amount of water delivered in gallons per minute at a given pumping head, in feet. In other words, the OPE is the percentage of how much water horsepower is needed by the pumping plant from the input horsepower to the motor.

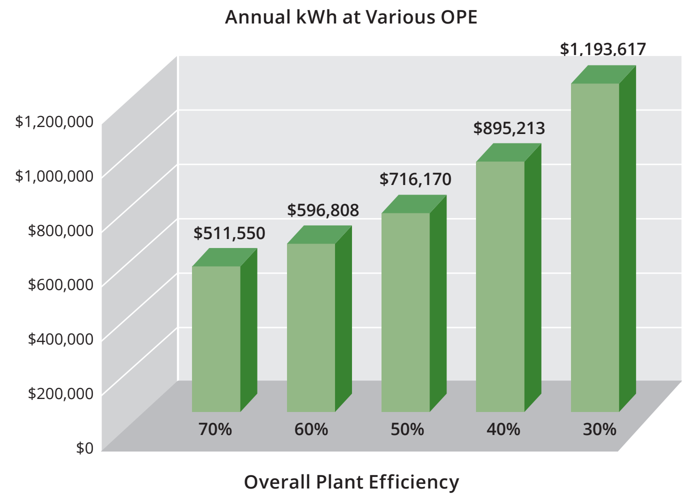
$$\frac{\text{Output HP}}{\text{Input HP}} = \text{OPE}$$

Using Energy Efficiently

Energy input to water output is a key component of the OPE. The pumping plant's power source takes electrical energy and converts it into the rotating mechanical energy of the pump impeller. The pump itself takes the mechanical energy and converts it to fluid energy, moving water at a certain pressure and flow.

In the simplest terms, the more efficient the pumping plant, the lower your energy bill to move the same amount of water.

Example of energy usage to pump 1,000 Acre Feet at 350 Total Head and $.14/kWh



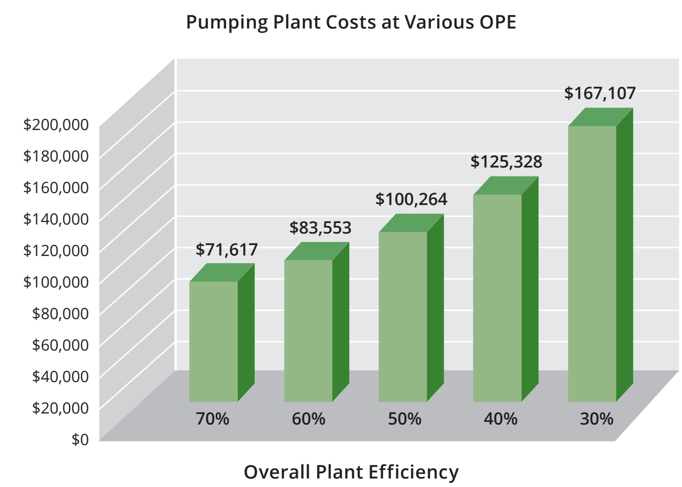
The OPE Rating

The OPE, presented as a percentage, is a key measure for evaluating your system's performance and is an integral part of maintaining high-quality pumping-system management.

The OPE rating is determined by various factors including:

- Bowl efficiency — the pump's efficiency at converting mechanical energy to moving water
- Driver efficiency — the efficiency of the electric motor

Example of cost to pump 1,000 Acre Feet at 350 Total Head and $.14/kWh



- Transmission shaft efficiency — a measure of losses that occurs in transmission
- Frictional Losses — losses due to mechanical friction within plant, pipe, pump and equipment

OPE can only be measured by a pump test and is the most critical finding of a pump test, taking into account and using all of the test's measurements. To help you gauge what the overall efficiency of your pumping plant actually is, we will test your pumps free-of-charge within the established program guidelines.

How OPE Relates to Performance

"Wire-to-Water" efficiency of a pumping plant is the ratio of work done by a pumping plant to the energy put into the pump. The pumping plant is defined as the pump and motor equipment and controls; including all associated fittings from the water source through the pump to the discharge into the distribution system.

An OPE in the **low to fair range suggests that a pump may need a retrofit, repair, or adjustment,** or that the pump is not matched to the current required operating conditions. For example, the water table may have dropped significantly over time, increasing the total lift above the original specifications.

The OPE values for pumps with submersible motors are viewed slightly differently. The efficiency for a submersible motor is generally 3-5% lower than a standard motor because of electrical energy line losses going down the well.

Overall Plant Efficiency Ranges: Wire to Water

Table of OPE performance ranges for surface mounted motor pump plants

Motor HP	Low	Fair	Good	Excellent
3 - 5	41.9 or less	42 - 49.9	50 - 54.9	55 or above
7 - 10	44.9 or less	45 - 52.6	53 - 57.9	58 or above
15 - 30	47.9 or less	48 - 55.9	56 - 60.9	61 or above
40 - 60	52.9 or less	53 - 59.9	60 - 64.9	65 or above
75 - up	55.9 or less	56 - 62.9	63 - 68.9	69 or above

Note: Submersible wells OPE values are 3 - 5% less than surface mounted motor pump plants OPE values.

When the results of a pump test identify a low OPE, it could be financially beneficial to investigate the problem area(s) and make the necessary adjustments or repairs.

The Benefits of Knowing Your OPE

Knowing your OPE and making system changes to operate at high-performance levels yield positive benefits that could save energy and save money. The tables on page 5 along with the results on page 17 will help to demonstrate these benefits.

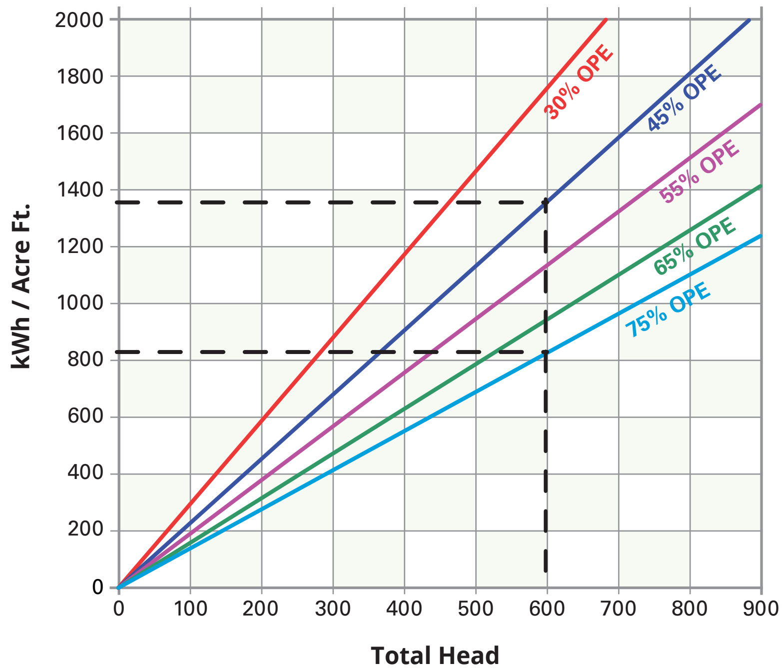
- Lower your current pumping requirements with conscientious pumping-system management
- Reduce total energy use for any amount of water pumped by lowering the kilowatt-hours required to pump an Acre Foot
- Track trends for budgeting and forecast potential problems

Ongoing System Management

Pumping-plant efficiency should be monitored regularly through accurate record keeping. We can also help you investigate the problems with pumps that test at a low OPE. Additionally, we have a variety of programs that can help you address problem areas and lower your energy cost. Many of these programs also offer incentives such as hardware discounts, rebates and more.

Example of Total Savings by Improving OPE

The graph below is an example of the relationship of kWh Consumption, Total Head and OPE.



If Your Total Head = 600 Ft.

Looking at the graph:

- **Your kWh/Per Acre Foot @ 45% OPE = 1364**
- **Your kWh/per Acre Foot @ 75% OPE = 818**

Using $0.14 per kWh:

- **Cost to pump Acre Foot of Water @ 45% OPE = $150**
- **Cost to pump Acre Foot of Water @ 75% OPE = $90**

Total Savings per Acre Ft. if OPE is improved = $60/Acre Ft.

If your annual water requirement were 200 Acre Ft.:

- **Annual Cost @ 45% OPE = $30,000**
- **Annual Cost @ 75% OPE = $18,000**

YOUR TOTAL ANNUAL SAVINGS IF IMPROVED $12,000/YEAR

Note:
Reducing Total Head through operational changes can also save energy by reducing the amount of work (kWh) required to pump desired amount of water (Acre Ft).

2.1 PUMPS AND HOW THEY WORK

Selecting the right pump for the task of moving water in the volume needed is where pumping efficiency begins. There are various types of pumps, with different types or numbers of impellers, the key pump component.

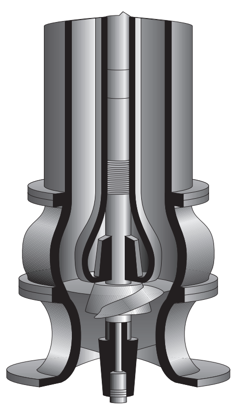
There are many different pump applications, types and sizes. Pumps are broadly classified as being either centrifugal or positive displacement.

The principal pump type utilized in water industry pumping applications is the centrifugal pump. Centrifugal pumps work by adding kinetic energy to a fluid using a spinning impeller (much like a fan blowing air). Centrifugal pumps are characterized by having a variable flow/head relationship. Head is determined by the amount of lift or pressure resistance a pump must overcome in an application. A centrifugal pump will generate less flow with increasing head requirements. A centrifugal pump's performance is described by its performance curve (please refer to pump performance curves on page 22), which charts the flow rate in relation to head (pressure or lift requirements).

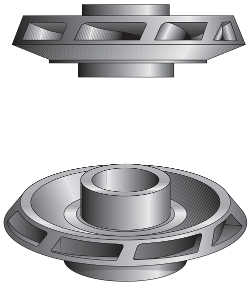
The type of centrifugal pump used or needed for the job should be based on the water and pumping requirements. There are, therefore, a handful of factors to take into consideration when designing a pumping system. **It is important to be knowledgeable of the required operating conditions and the variety of pump types and motors available to ensure that your system operates at the highest efficiency for those conditions.**

The Impeller

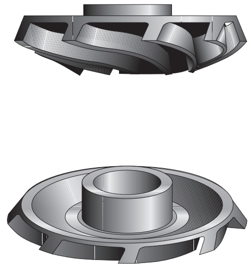
There are several impeller designs: **Axial** (open), **Radial** (closed) or **Mixed** (semi-open).



Axial Flow impellers are typically used in agriculture in canal lift pumps, where water flows in a straight line. They provide very high flows at relatively low pressure.



Radial Flow impellers are most often used in booster pumps, and are also used in horizontal centrifugal pumps and deep wells. They produce generally high pressures at lower flows. Water flow through a closed impeller takes a 90° turn.



Mixed Flow impellers help the water flow through and out of the impeller at an angle less than 90°.

Centrifugal Pump Types

Turbine Pump

The vertical turbine type centrifugal pump is configured as its name implies. The motor (driver) is vertically mounted above the pump's discharge head and is coupled to the turbine pump via a vertical shaft. The vertical turbine pump operates inside the pump casing below the water level (well applications/booster with lift applications) or to a water source under pressure. One or more sets of impellers and bowls on the shaft are assembled into a unit called the bowl assembly, which is the actual pumping element. The advantage of the turbine type pump is its smaller and more compact design. This allows the pump to be installed in relatively small diameters in shallow or deep pumping applications. It also affords flexibility for ease of maintenance and redesign. SCE defines these as a turbine well or turbine booster on test reports and are defined by applications.

Submersible Pump

A submersible pump has a waterproof electric motor connected directly to a turbine pump. As the name implies, both the pump and its motor are in the water. A submersible pump is typically used when the space above ground is at a premium or a straight-line access to the water source is not possible. A submersible pump is also much quieter than pumps that are above ground, which is sometimes desired. SCE defines these as a submersible well or submersible booster on test reports and are defined by applications.

Horizontal Pump

The horizontal centrifugal pump is usually a single-stage unit with one impeller mounted on a horizontal axis. The water enters the center of the rotating impeller and forces the water out radially to the outer diameter of the pump chamber, where it gains energy and is discharged. This action draws in more water to achieve a continuous flow. These are centrifugal boosters. They are not used for well applications.

A suction lift of up to 15 feet is possible with this type of pump and it can deliver up to 70,000 gallons of water per minute. The centrifugal pump operates best when the water flows by gravity to the intake end of the pump. Centrifugal pumps are relatively simple in design and are inexpensive.

2.2 THE PUMP TEST

A pump test is the **key step in measuring OPE**. The end result of a pump test is an estimate of the overall efficiency of your pump and the total cost of running it under the conditions of the test.

SCE's Pump Test Program

Our Pump Testers conduct complete and accurate efficiency tests on water pumps free-of-charge within the established program guidelines. The goal of the program is to assist customers in making the most efficient use of every kilowatt of electricity to save energy and money. Frequently, we also offers energy efficiency cash incentives and rebates applicable to pump plant operations. Ask your SCE Pump Tester about the availability of these programs.

Reasons for Testing

If an existing pump has undergone a mechanical breakdown and is operating in a sub par manner, most likely energy is being wasted. Usually the inefficiency is caused by wear, particularly in well applications where water may contain particulates, such as sand. Also, if the pump is simply not able to produce the required flow and pressure needed, a repair, retrofit or replacement may be needed.

New pumps should also be tested. A test on a new pump will establish baseline performance for future comparison and verify that equipment is operating as designed.

What a Pump Test Measures

A pump test measures various aspects of the pump while in operation to determine OPE:

- Rate of flow
- Total Head
- Power input to the pumping plant

The illustrations on pages 14 and 15 show typical pump plant applications.

Preparing for a Pump Test

An SCE pump test representative will need information regarding the pump's management and design to do a complete cost analysis. This information includes the following:

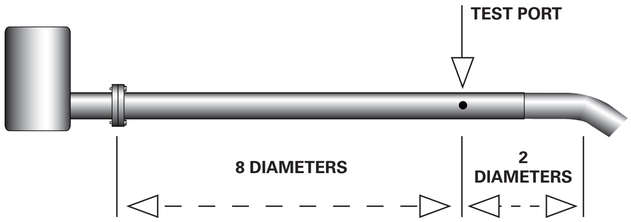
- Hours of operation
- Normal operating conditions
- Required flow rate
- Discharge pressure
- Description of system (where is the water going?)

Meeting Test-Ready Requirements

On the day of the test, the Pump Tester will need:

- Sounding Location (Sounding tube or opening/ hole outside of casing)
- Suitable Location for Flow Determination
- Ability to interrupt operations for equipment setup (in some instances, a corporation valve allows for testing without shutdown)
- Ability to run equipment for extended period (30 minutes to 2 hours typically)

In order to obtain an accurate measurement, the water flow in the pipe must be free from turbulence. Your SCE pump test representative will answer any questions you have on access requirements.



Receiving Test Results

After the test is completed, you will receive a detailed report of your results including data gathered, as well as recommendations regarding financial and energy savings that may be derived by improving pumping productivity.

With a pump test and the expertise of your pump test representative, you will be able to identify which pumps to examine, evaluate, and perhaps replace, repair or retrofit. The results of the evaluation will also show what your annual savings in energy could be if you address problem areas and make changes that improve the OPE of any or all pumping plants. A sub par test result may also lead to an examination of your system for other potential problem areas. Your pump test representative will be able to explain the yearly changes, cost of operations and suggest potential solutions.

The Importance of Regular Pump Testing

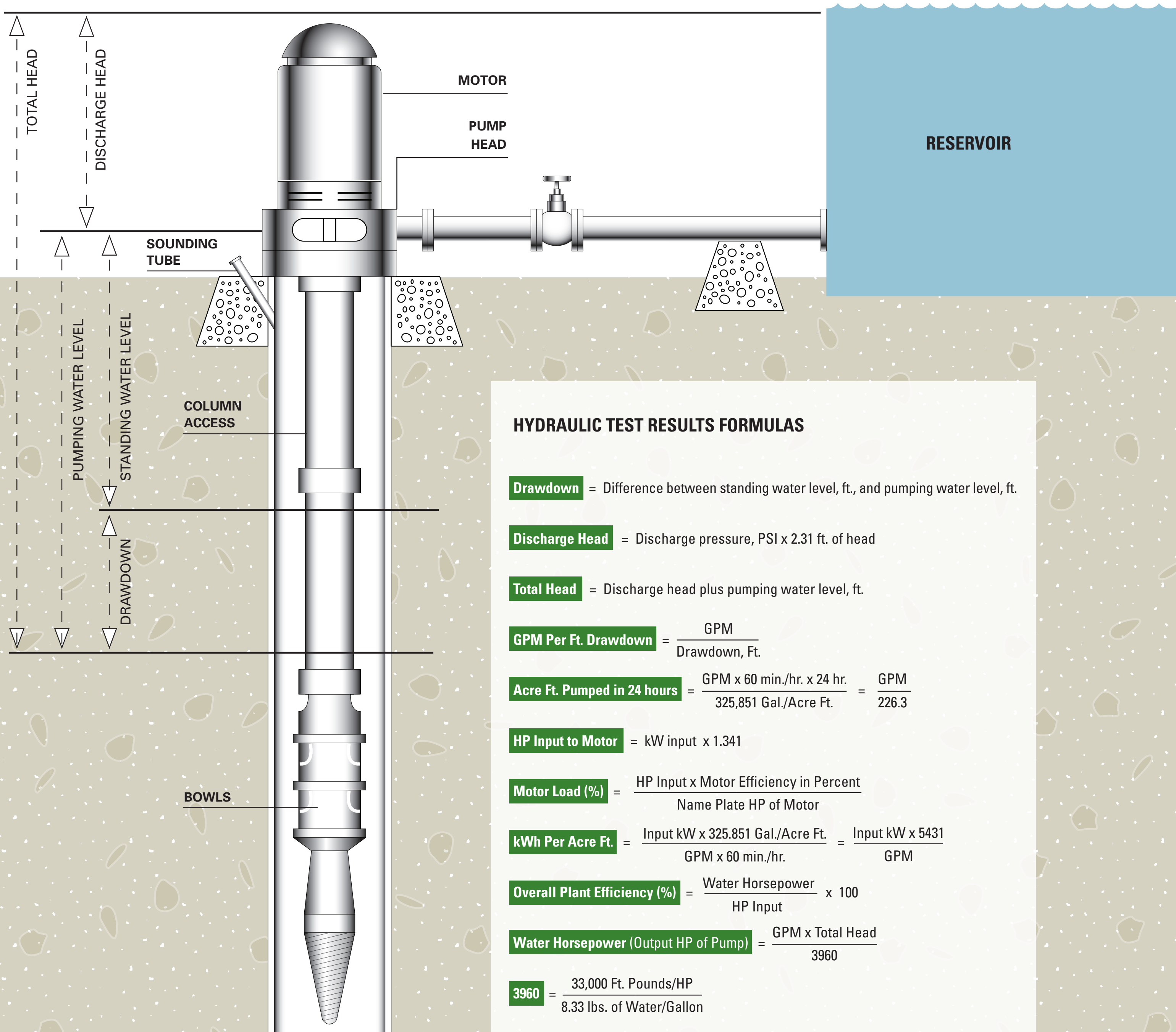
A pump should be tested every one to three years, depending on the annual usage and severity of operating conditions. For example, you may want to test a well pump that pumps a lot of sand-filled water yearly, but test a booster pump supplied by clean water once every three years.

Having tests conducted on a routine basis allows you to evaluate the systems condition over time. For wells, GPM/FT of drawdown can be evaluated over time to show condition of well efficiency (how well the water is being fed to pump).

Regular pump testing cannot only help maintain efficiency and keep energy costs in check — it can also help prevent a serious problem from arising, including a system breakdown. Pinpointing a potential problem allows you to investigate the situation and perform an objective economic analysis to identify when it is financially beneficial to make changes to the system, including possible pump repairs or retrofitting.

See pages 17-20 for samples of SCE'S testing reports.

Deep Well Turbine Application



HYDRAULIC TEST RESULTS FORMULAS

Drawdown = Difference between standing water level, ft., and pumping water level, ft.

Discharge Head = Discharge pressure, PSI x 2.31 ft. of head

Total Head = Discharge head plus pumping water level, ft.

GPM Per Ft. Drawdown = $\frac{\text{GPM}}{\text{Drawdown, Ft.}}$

Acre Ft. Pumped in 24 hours = $\frac{\text{GPM x 60 min./hr. x 24 hr.}}{\text{325,851 Gal./Acre Ft.}} = \frac{\text{GPM}}{226.3}$

HP Input to Motor = kW input x 1.341

Motor Load (%) = $\frac{\text{HP Input x Motor Efficiency in Percent}}{\text{Name Plate HP of Motor}}$

kWh Per Acre Ft. = $\frac{\text{Input kW x 325.851 Gal./Acre Ft.}}{\text{GPM x 60 min./hr.}} = \frac{\text{Input kW x 5431}}{\text{GPM}}$

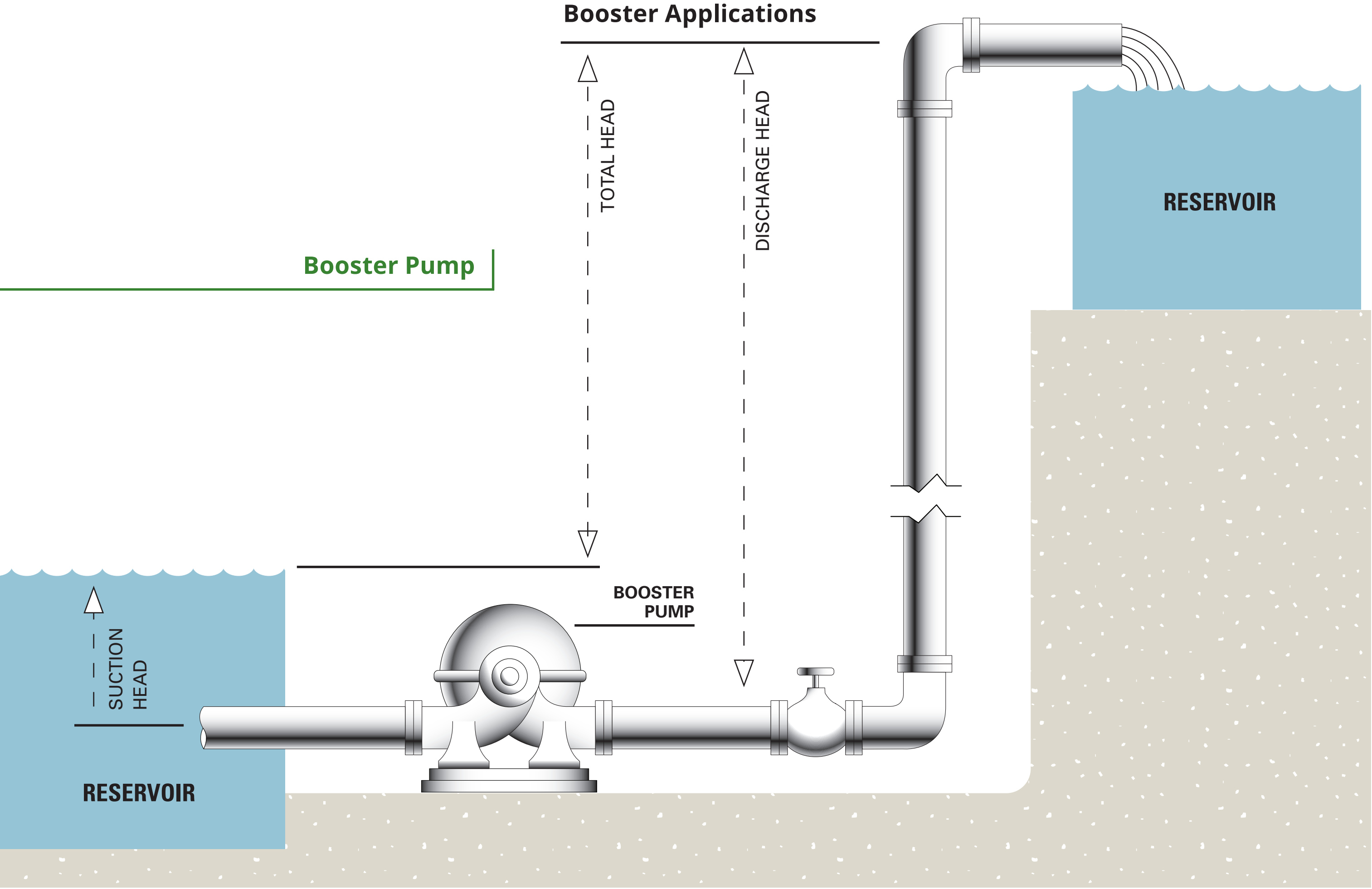
Overall Plant Efficiency (%) = $\frac{\text{Water Horsepower}}{\text{HP Input}}$ x 100

Water Horsepower (Output HP of Pump) = $\frac{\text{GPM x Total Head}}{3960}$

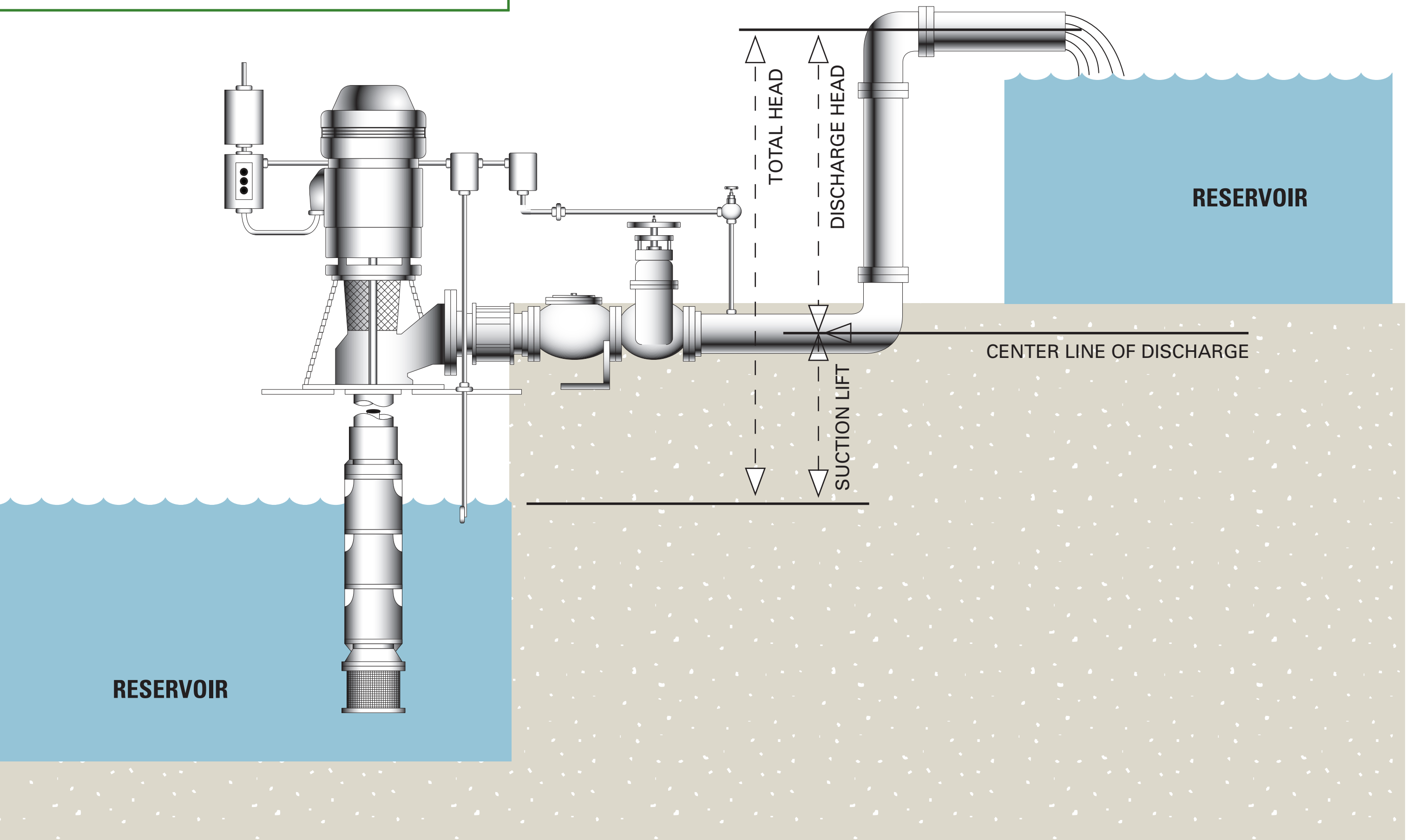
3960 = $\frac{\text{33,000 Ft. Pounds/HP}}{\text{8.33 lbs. of Water/Gallon}}$

Booster Applications

Booster Pump



Turbine Booster



Pump Test Key Terms

These key terms are associated with your plant's pumping system and are an important part of the pump test report developed by an SCE technician:

Discharge Pressure, PSI – The pressure obtained at centerline of pump discharge pipe using a calibrated gauge (psig). Discharge pressure is converted to feet and expressed as 'Discharge Head'.

Standing Water Level, Feet – The well's water level obtained when pumping plant is at rest, also referred to as Static Water Level.

Drawdown, Feet – The measured distance, in feet, that the well's water level changes from standing/ static level to operating pumping level during observed test conditions.

Suction Head – Head (in units of feet) measured above center line of pump suction intake. Most often obtained with calibrated bourdon tube pressure gauge (suction pressure) and converted to feet by conversion factor 2.31 ft. water/psi.

Suction Lift – The distance in feet between pump discharge head and water level. Typically measured utilizing measuring tape or via calibrated vacuum pressure gauge.

Discharge Head Feet – Head (in units of feet) measured above center line of pump discharge pipe. Most often obtained with calibrated bourdon tube pressure gauge (discharge psig); pounds per square inch are converted to discharge head by conversion factor 2.31 ft. water/psi.

Pumping Water Level, Feet – The well's operating water level below center line of discharge pipe as observed during test conditions.

T**otal Head, Feet** – The sum of the water head above and below the center line of the pump discharge pipe. For well applications, the Total Head is the sum of the Discharge Head and the Pumping Water Level. For booster applications, the Total Head is either determined by subtracting the Suction Head from the Discharge Head or by adding the Suction Lift to the Discharge Head. Total Head is used in determination of water horsepower. It is also useful as a comparison and evaluation of current operations to the pump's design point and/or to past pump operations/conditions.

Capacity, GPM – Flow expressed in gallons per minute. This flow is obtained through the use of SCE equipment (in most instances a Pitot tube). Capacity is used to calculate water horsepower.

GPM per Foot Drawdown – The ratio of capacity (GPM) to drawdown feet. GPM/Ft Drawdown is useful in determining the well's performance, trending well performance year-to-year, and may provide information to be used in designing proper pump to meet application. Factors that may affect the well's performance include (but are not limited to); aquifer conditions, well casing diameter, well screen/strainer, the gravel pack and/or the initial design of the well and pump. This reading is a measure of well performance, not pump performance.

Acre Feet Pumped in 24 hours – Amount of water, in Acre Feet, pumped per day at the measured capacity, GPM. One Acre Foot of water is equivalent to 325,851 gallons of water.

kW Input to Motor – Input kW determination obtained through timing of SCE electronic meter or by calibrated handheld electronic kW meter. The kWh input is converted to horsepower to calculate input horsepower.

HP Input to Motor – The power input to driver, expressed in horsepower obtained by converting input kW to horsepower (1.341 kW per 1 horsepower).

Motor Load (%) – The calculated motor load based on the ratio of brake horsepower (horsepower at motor output shaft obtained by factoring motor efficiency) to nameplate horsepower. Brake horsepower is equal to horsepower at the output shaft of motor. The motor load should be generally between the ranges of 70% to 115%.

Measured Speed of Pump, RPM – Measured rotational speed, revolutions per minute, of pump shaft as determined by tachometer.

kWh per Acre Foot – The amount of Kilowatt Hours required to pump one Acre Foot of water. Value obtained using pump test results. Useful in determining pumping costs. Cost to pump an Acre Foot of water can be calculated by multiplying this value by the current cost/kWh.

Overall Plant Efficiency (%) – The ratio of the water horsepower (the overall output of plant) to input horsepower (the power input). The overall output can also be defined as the amount of horsepower required to deliver the measured capacity (water gallons per minute) at the measured Total Head (in feet). Overall plant efficiency is used in determining overall condition of pumping plant at observed test conditions. Two main components that contribute to Overall Plant Efficiency: Motor Efficiency and the Pump Efficiency.

Customer Meter, GPM – Flow as indicated by customer meter.

Test Results: Inefficient Pump

The following two letters are samples of communications you would receive when the Overall Pump Plant Efficiency (OPE) result of one your pump plants is inefficient. These samples can be compared to the example of the energy cost of an inefficient pump as shown on page 5 of this manual.

SOUTHERN CALIFORNIA EDISON®
Energy for What's Ahead®

Confidential / Proprietary

June 19, 2018

Mr. Joe Water
ABC Water District
1000 Main Street
Anytown, CA 90000

HYDRAULIC TEST RESULTS: Plant Well #6
Location: 5050 Main St, Anytown, CA 90000
Cust. #: 0-000-000 Serv. Acct. #: 000-0000-00
Meter: P000000 Pump Ref. #: 0000

In accordance with your request, a test was made on your turbine well pump on June 1, 2018. If you have any questions regarding the results with follow, please contact YOUR SCE PUMP TEST REPRESENTATIVE at (XXX) XXX-XXXX.

Equipment
HP: 150
Pump Mfg.: PEERL No.: 205663
Motor Mfg.: US No.: 1325283

RESULTS	
Discharge Pressure, PSI	**82.4**
Standing Water Level, Feet	**142.2**
Drawdown, Feet	**17.5**
Discharge Head, Feet	**190.3**
Pumping Water Level, Feet	**159.7**
Total Head, Feet	**350.0**
Capacity, GPM	**659.0**
GPM per Foot of Drawdown	**37.7**
Acre Ft. Pumped in 24 Hours	**2.913**
kW Input to Motor	**78.8**
HP Input to Motor	**105.7**
Motor Load (%)	**64.5**
Measured Speed of Pump, RPM	**1784**
Customer Meter, GPM	**660.0**
kWh per Acre Foot	**649**
Overall Plant Efficiency, (%)	**55.1**

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Manager
Hydraulic Services

The letter above details the pump test results which in this sample reflect an OPE of 55%. Please see the illustration on page 4 and example on page 5.

2.3 PUMPING TEST COST ANALYSIS

When your pump test is completed, you will receive a report from SCE showing the results of your test, indicating **the pumping plant's OPE and other important information related to energy and water savings.** The statistics will help you see how your pump is performing and what affect a pump repair or retrofit may have on energy efficiency and savings.

If your OPE is low, we will provide you with a Pumping Cost Analysis, which compares your plant's present operating performance to what it could be if it were operating in optimal conditions. On the next page is an example of the Pumping-Cost Analysis of a pump test report prepared by SCE's technicians.*

Important: The pumping cost analysis presented is only valid for the assumptions listed in lines 1-5 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 or repair a pump.

Explanation of the Pumping Cost Analysis

The cost analysis is based on assumptions that water requirements will remain the same and all operating conditions remain the same (Total Head and Water Demand). Based on these assumptions, the cost analysis letter will estimate the following:

1. Estimated potential improvement in OPE
2. Estimated energy savings kWh/Year and $/Year

Below are the calculations that determine the potential savings that can be obtained by improving OPE:

3. **Total kWh** – The total kilowatt hours used annually based on hours of operation and 12-month billing average
4. **kW Input** – Input kW as measured by test representative
5. **kWh per Acre Foot** – The kilowatt-hours required to pump an Acre Foot of water into the system
6. **Acre Feet per Year** – The estimated Acre Feet per year pumped into the system
7. **Average Cost per kWh** – The average cost per kilowatt-hour based on previous 12-month billing
8. **Average Cost per Acre Foot** – The average cost to pump an Acre Foot of water through the system
9. **Overall Plant Efficiency (%)** – The overall pumping plant efficiency (which may be zero in the case where the pumping water level in a well cannot be measured for some reason)
10. **Total Annual Cost** – The estimated annual cost of energy 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

**NOTE: Other tests may provide other types of information.*

Cost Analysis: Inefficient Pump

SOUTHERN CALIFORNIA EDISON®
Energy for What's Ahead®

Confidential / Proprietary

June 19, 2018

Mr. Joe Water -
ABC Water District -
1000 Main Street -
Anytown, CA 90000 -

PUMPING COST ANALYSIS: Plant Well #6
Location: 5050 Main St, Anytown, CA 90000
Cust. #: 0-000-000 Serv. Acct. #: 000-0000-00
Meter: P000000 Pump Ref. #: 0000

The following energy efficiency analysis is presented as an aid to your cost accounting. This is an estimate based on the conditions present during the Edison pump test performed on May 1, 2018, billing history for the past 12 months, and your current rate of TOU-PA2B.

Assuming the water requirements will be the same as for the past year, and all operating conditions (annual hours of operation, head above and water pumping level) will remain the same as they were at the time of the pump test, it is estimated that:

1. Overall plant efficiency can be improved from 55.1% to 72%.
2. This can save you up to 101,203 kWh and $14,168 annually.
3. These kWh savings translate to a 132.98-ton decrease in CO_2 emissions

Plant Efficiency

	Existing	Improved	Savings
Total kWh	**533,472**	**432,269**	**101,203**
kW Input	**78.8**	**63.8**	**14.9**
kWh per Acre Foot	**649**	**497**	**152**
Acre Feet per Year	**822**		
Average Cost per kWh	**$0.14**		
Average Cost per Acre Foot	**$90.86**	**$73.62**	**$71.54**
Overall Plant Efficiency (%)	**55.1**	**72.0**	
Total Annual Cost	**$74,686**	**$60.518**	**$14,168**

It is sincerely hoped that this information will prove helpful to you, and that your concerns over - maintaining optimum energy efficiency will be continued. If you have any questions regarding this - report, please contact SCE PUMP TEST at (909) 820-5519. -

Manager
Hydraulic Services

The letter above provides a cost analysis of your existing pump performance at an OPE of 55% and the potential $13,758.26 savings if the pump were operating at an improved OPE of 72%. Frequently, we offers incentives based on energy cost savings for customers improving their OPE through repairs or retrofits. Ask your SCE account manager or pump tester about available incentives and rebates. Please see the illustration on page 4 and example on page 5.

Test Results: Efficient Pump

SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead®

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June 19, 2018

Mr. Joe Water
ABC Water District
1000 Main Street
Anytown, CA 90000

HYDRAULIC TEST RESULTS: Plant Well #6
Location: 5050 Main St, Anytown, CA 90000
Cust. #: 0-000-000 Serv. Acct. #: 000-0000-00
Meter: P000000 Pump Ref. #: 0000

In accordance with your request, a test was made on your turbine well pump on June 1, 2018. If you have any questions regarding the results with follow, please contact YOUR SCE PUMP TEST REPRESENTATIVE at (XXX) XXX-XXXX.

Equipment
HP: 150
Pump Mfg.: PEERL No.: 205663
Motor Mfg.: US No.: 1325283

RESULTS	
Discharge Pressure, PSI	**85.0**
Standing Water Level, Feet	**148.3**
Drawdown, Feet	**18.7**
Discharge Head, Feet	**196.4**
Pumping Water Level, Feet	**167.0**
Total Head, Feet	**363.4**
Capacity, GPM	**935.0**
GPM per Foot of Drawdown	**50.0**
Acre Ft. Pumped in 24 Hours	**4.133**
kW Input to Motor	**88.0**
HP Input to Motor	**118.0**
Motor Load (%)	**72.0**
Measured Speed of Pump, RPM	**1,784**
Customer Meter, GPM	**936.0**
kWh per Acre Foot	**511**
Overall Plant Efficiency, (%)	**72.7**

It is sincerely hoped that this information will prove helpful to you, and that your concerns over maintaining optimum energy efficiency will be continued. If you have any questions regarding this report, please contact SCE PUMP TEST at (909) 820-5519.

Manager
Hydraulic Services

The letter above is used to communicate the detailed test results of a pump that was determined to be operating efficiently.

Test Results: Efficient Pump — Congratulations

SOUTHERN CALIFORNIA EDISON
Energy for What's Ahead®

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June 19, 2018

Mr. Joe Water
ABC Water District
1000 Main Street
Anytown, CA 90000

PUMPING COST ANALYSIS: Plant Well #6
Location: 5050 Main St, Anytown, CA 90000
Cust. #: 0-000-000 Serv. Acct. #: 000-0000-00
Meter: P000000 Pump Ref. #: 0000

The following energy efficiency analysis is presented as an aid to your cost accounting. This is an estimate based on the conditions present during the Edison pump test performed on May 1, 2018, billing history for the past 12 months, and your current rate of TOU-PA2B.

Assuming the water requirements will be the same as for the past year, and all operating conditions (annual hours of operation, head above and water pumping level) will remain the same as they were at the time of the pump test, it is estimated that:

	Existing
Total kWh	**420,000**
kW Input	**88.0**
kWh per Acre Foot	**511**
Acre Feet per Year	**821.7**
Average Cost per kWh	**$0.14**
Average Cost per Acre Foot	**$71.54**
Overall Plant Efficiency (%)	**72.7**
Total Annual Cost	**$46,200.00**

The hydraulic test results indicate that this pump is operating in an efficient manner.

It is sincerely hoped that this information will prove helpful to you, and that your concerns over maintaining optimum energy efficiency will be continued. If you have any questions regarding this report, please contact SCE PUMP TEST at (909) 820-5519.

Manager
Hydraulic Services

The above letter provides the energy cost detail information of a pump that was tested and found to be operating efficiently. This information can be used as a historical baseline for future tests and to assist you with energy cost budgeting for your operations.

2.4 PUMP PERFORMANCE CURVES

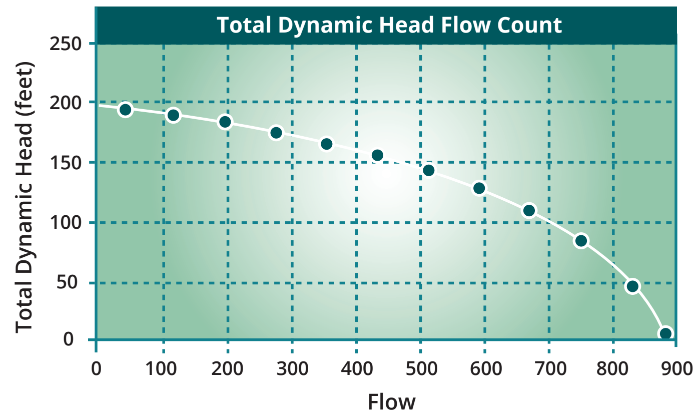
Pumps have the ability to perform in a range of operating conditions. To help users understand this important information and use it to their advantage and their particular pumping plant needs, pump manufacturers publish pump performance curves for each pump type. Overlaying a pump performance curve on pump test result figures can **provide further insights into actual pump performance.**

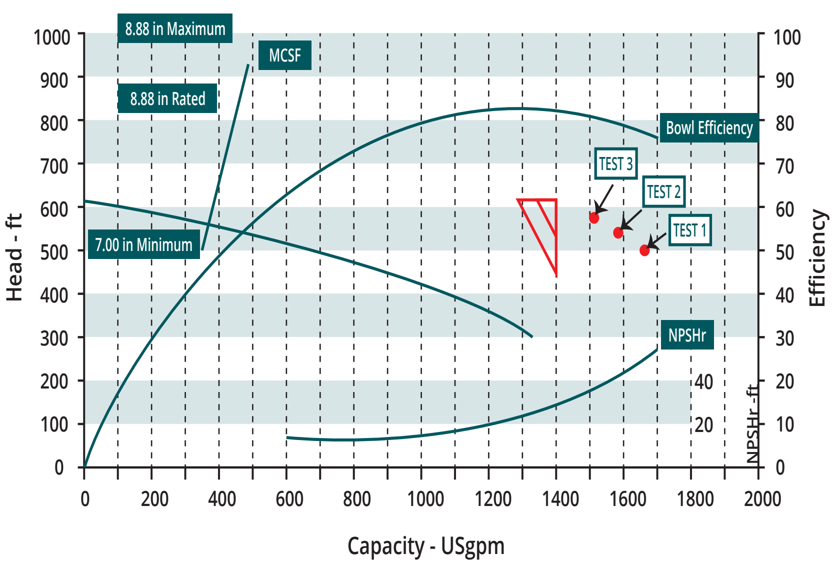
A pump performance curve is a charted or graphed illustration that portrays a pump's range of operating conditions. A simple pump performance curve will show the relationship between pump flow (in gallons per minute), pumping pressure (measured in feet), water horsepower and Net Positive Suction Head (NPSH).

Why They Are Useful

Pump-performance curves can help you see what **effect increasing or decreasing pumping pressure will have on pump production** (measured in gallons per minute or GPM) and horsepower requirements.

You can take the results of a SCE hydraulic pump-efficiency test and superimpose them onto the manufacturer's pump-performance curve to determine actual pump operating conditions with respect to design and also to give indications of excessive pump wear.





PUMP TEST RESULTS	TEST 1	TEST 2	TEST 3
Standing Water Level, Feet	191	191.0	191.0
Drawdown, Feet	62.3	60.3	58.2
Discharge Head, Feet	249.5	288.8	323.4
Pumping Water Level, Feet	253.3	251.3	249.2
Total Head, Feet	502.8	540.1	572.6
Capacity, GPM	1,654	1,588	1,518
GPM per Foot Drawdown	26.5	26.3	26.1
Acre Feet Pumped in 24 Hours	7,311	7,019	6,710
kW Input to Motor	233.9	235.2	236.1
HP Input to Motor	313.7	315.4	316.6
Motor Load (%)	100.2	100.7	101.1
Measured Speed of Pump, RPM	1,787		
Customer Meter, GPM	1,690		
kWh per Acre Foot	768	804	845
Overall Plant Efficiency (%)	67.0	68.7	69.3

FREQUENTLY ASKED QUESTIONS

1. **How long does it take to conduct a pump efficiency test?**
   An average pump test takes one to three hours. This includes approximately 30 minutes preparation time and 30 minutes to 2 hours pumping plant run time.

2. **How much does the pump efficiency test cost?**
   There is no charge for the pump test for eligible customers, other than associated energy costs.

3. **Who can fix my pump?**
   Just take your pump efficiency test results to a qualified pump contractor to make efficiency improvements to your pumping plant.

4. **How do I request a pump test?**
   There are three ways to request a pump test.
   1. You can call one of the numbers depending on where your plant is located:
      - L.A. Area, Orange County, San Bernardino County — 1-800-634-9175
      - San Joaquin Valley — 1-800-634-9175
   2. You can request a form by emailing **HydraulicServices-PumpTest@sce.com.**
   3. Contact your assigned SCE account manager.

5. **How often should I get a pump test?**
   The recommended frequency of testing is dependent on many factors. These factors include pump annual operation hours, annual energy consumption, changes in your pumping conditions and concerns specific to the pumping plant. As a general rule of thumb, we recommend that a well pump with average to high usage be tested every one or two years. For booster pumps, the recommended testing frequency is every two to three years.

6. **What are some simple things I can do to reduce my costs?**
   There are several ways to reduce your pumping energy costs. Maintenance options include adjusting bowl and impeller assembly, pump overhaul or replacement, and/or well rehabilitation. If you operate multiple pumps, you can utilize test results to prioritize pumping so that the most efficient and lower cost pump(s) act as the lead. Reductions in system pressures and frictional losses also help to reduce costs.

7. **How come my efficiency is not at 100%? It's new.**
   Our pump test measures the Overall Plant Efficiency which includes the combined Motor and Pump Efficiency along with the frictional and electrical losses associated with the plant. Depending on the type and size, motor efficiencies generally range between 85-96%. The same goes for pumps which vary in efficiency, depending on type, size, and manufacturer. Generally, these range from 70-80%.

8. **What do I need to do to allow for a pump test?**If you need assistance determining what is needed to conduct a test, please contact us using the numbers provided in #4. In general, the following is required to conduct a complete test:
   - Ability to start and stop pump for instrument hook-up or proper fittings for instrumentation hook-up while pump is running
   - Pumping plant needs to run long enough to conduct test. (usually 30 minutes to 2 hours)
   - Ability to measure Water Flow using test equipment or customer water meter
   - Ability to measure Electrical Input
   - Ability to sound for pumping and standing water levels in wells
   - Ability to measure Total Head. Inlet Pressure, Discharge Pressure, Pumping Level for wells

9. **What size HP pump can we test?**
   Depending on plant configuration, we can test pumping plants ranging from <25 HP and up.

10. **What kind of pumps does SCE test?**
    We test pumps for agricultural, municipal and industrial customers as long as the application delivers water to an end use, and the plant configuration allows for measurement of flow, feet of head and electrical power input. These pumps include deep well turbines, turbine boosters, centrifugal boosters and submersible well or booster pumps.

3.2

Enhanced Services

Through the utilization of our services, customers have improved their system reliability and reduced emergency repair costs as a direct result of detecting potential equipment problems before catastrophic failures occur. This early detection and system reliability has typically saved our customers thousands of dollars in the annual cost of their system operations.

Electrical Panel Infrared Inspection and Analysis

We will inspect designated electrical panels to identify poor electrical connections using an infrared thermal imaging camera.

- Electrical equipment tends to heat up before it fails. However, many problems can be concealed by insulators and other objects that can go undetected by the naked eye. Using a thermal imaging camera, an SCE hydraulic test specialist will inspect your electrical panel to identify poor connections — locations where energy is wasted and can cause electrical arcing and even fires to develop. By scanning electrical cabinets, breaker panels, fuses, bolted connections and switchgear with a thermal imager, the test specialist can get an instant picture of impending trouble that may have otherwise gone unnoticed.
- In addition to identifying hot spots, the technician will provide analysis of temperature measurements so you know when equipment has exceeded its temperature limit and needs to be taken offline for replacement or repair. By acting proactively, you can often remedy minor problems before they become major issues.

Motor and Pump Vibration Detection

We will measure the frequency and magnitude of vibrations produced by designated equipment using an accelerometer or similar instrument and deliver written test results which may include possible causes of vibrations if the vibrations exceed certain levels.

- Excessive vibration in your motor and pump system can significantly reduce the life of your equipment. Additionally, a portion of the energy delivered to it is lost due to friction. Our vibration detection service can help determine the severity of your pumping system's vibration and what the root cause may be.
- Equipped with this information, you can develop a proactive maintenance program about what repairs or adjustments should be made to protect your equipment and improve system efficiency. Furthermore, you can identify which equipment may need to be monitored more closely to avoid potential problems in the future.

Pump Efficiency Test

We will perform a pump efficiency test following standard test procedures and provide written tests results.

- Our Pump Tester will evaluate your plant to identify potential system design changes that may lower operating costs and provide you with a better understanding of your system's condition. Test results can be used as a budgeting aid to determine your operating costs and prioritization of system pumping plant repairs or replacements, to optimize your pumping operations and evaluate your equipment's operational efficiency. Furthermore, by regularly participating in the program, you can track historical results for trends and record-keeping.

3.3 DESIGNING AND MAINTAINING AN EFFICIENT SYSTEM

There are many physical and design aspects of your pumping system that may affect its performance including the type of motors used, size of pipes, the actual pumping pressure and more. **Designing or redesigning your system with optimum operational efficiency will prove to be cost-effective over time** and could have an immediate positive impact of the cost and use of energy.

Energy-Efficient Motors

Motors are an essential part of your pumping system, converting electrical energy into mechanical work to move water. **They are not 100% efficient, however, since some electrical input is dissipated as heat**. Some electrical motors have less heat loss than others of comparable size.

Today, motors are designed to be more efficient and are able to convert a higher percentage of their electrical input to useful mechanical work. Motor manufacturers accomplish this by using higher-quality and more expensive materials, such as iron and copper.

Purchasing a new high-efficiency motor may be more economical overall (life cycle cost) than repairing a damaged motor, when you factor in the energy savings that a more efficient motor will deliver.

Example of savings:

Standard vs. Premium Efficient Motors

75% Motor Load and 6000 Hours of Operation

For more information, visit the U.S. Department of Energy's Best Practices Web page at **https://www.energy.gov/eere/femp/downloads/operations-and-maintenance-best-practices-guide**

Motor HP	Standard Efficiency Motor	Annual kWh 6000 Hours Operation	Premium Efficiency Motor	Annual kWh 6000 Hours Operation	Energy Savings kWh/Year	Energy Savings $/Year
25	90	93,240	93.9	89,339	3,901	$546
50	91.2	184,070	94.8	177,132	6,938	$971
100	92.7	362,038	95.4	351,813	10,225	$1,432
150	93.1	540,992	95.8	525,407	15,585	$2,182
200	93.5	718,630	95.8	700,470	18,160	$2,542
250	94.2	886,969	96.0	874,219	12,750	$1,785

Variable-Speed Drive

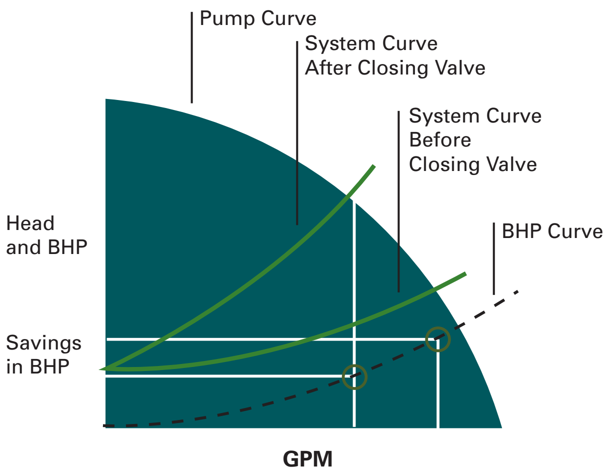
You can reduce pumping energy and costs by using a variable-speed drive (VSD) to control pressure and flow. A VSD-controlled pump can maintain constant pressure when the flow is changing. It can also be used to keep a constant flow when the pressure is changing. In either case, the result is optimum productivity with reduced energy usage.

A variable-speed drive improves a pump's performance by changing its rotational speed to better match the pumping load. The most efficient VSDs use solid-state inverters. A sensor in the pumping system signals the VSD circuits to vary the voltage and frequency outputs, which changes the pump speed.

Energy savings can be projected on a pump by comparing the estimated energy consumption of a fixed-speed pump to a variable-speed model, taking into account the flow characteristics of the pumping site.

Excessive Pumping Pressure

Effect of Closing Pump Discharge Valve



BHP = Brake Horsepower

Your pumping system should maintain the minimum pressure required to operate efficiently. Excessive pumping pressures can be the result of several causes:

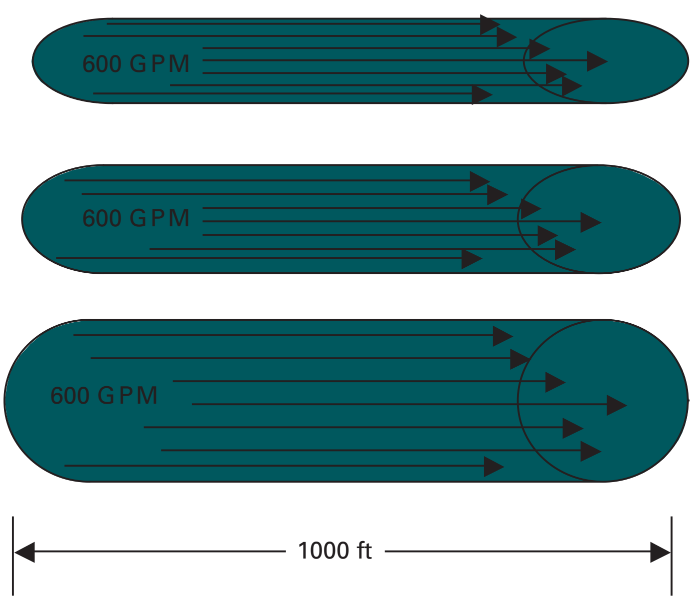
- A defective booster pump control and valves
- Pumping against a higher head than is needed to move water (false head)
- Supplying water at a pressure exceeding state regulations

System pumping pressures should be checked regularly to see that they meet but do not exceed pressure requirements.

Piping System Friction Losses

Large diameter pipes have less flow resistance per unit of flow than smaller pipes. Pipelines are usually sized enough to keep fluid velocities and Total Head losses at acceptable levels. The design involves a balance between capital expenditures for pipe, treatment requirements, system requirements and overall energy consumption based on design.

The figure below is a basic example of potential frictional losses for pumping water in varying diameters of 1,000 feet of straight new cast iron pipe.



Pipe Inside Diameter	~Velocity	~HEAD LOSS	~kWh/ Acre Ft
6″	7 ft./sec	29 ft.	43
8″	4 ft./sec	7 ft.	11
10″	2 ft./sec	2 ft.	4

**HAZEN - WILLIAMS METHOD FOR DETERMINING FRICTION LOSS. IRON PIPE = 130 FRICTION COEFFICIENT

Approximate cost per year using OPE = 69%, 500 Acre Feet pumped per year, and cost of energy at $ 0.14/kWh:

6 Inch Pipe = 500 Acre Ft. x 43 kWh/Acre Ft. = 21,500 kWh x $0.14 kWh = $ 3,010
8 Inch Pipe = 500 Acre Ft. x 11 kWh/Acre Ft. = 5,500 kWh x $0.14 kWh = $ 770
10 Inch Pipe = 500 Acre Ft. x 4 kWh/Acre Ft. = 2,000 kWh x $0.14 kWh = $ 280

Well Conditions and Pumping Costs

Well-specific capacity, which is the well flow rate divided by the drawdown for that flow rate, is a complex relationship based on the aquifer conditions, well casing diameter, well screen, grand pack selection and the initial development.

Well performance will generally degrade with time, due to a variety of causes. Well screens can corrode or encrust with various deposits that reduce flow openings into the well. Gravel packs can also experience plugging from fine materials such as silt. Attempting to pump too much water by using too big a pump for the aquifer also results in low well-specific capacity. This subject is very important to your pumping costs. Consult with your pump dealer and/or well driller if the pump test history reveals significant reduction in well-specific capacity over time.

3.4 SUPERVISORY CONTROL AND DATA ACQUISITION

Your business may be well suited for Supervisory Control and Data Acquisition (SCADA), an automated system that **maximizes pumping system savings with a minimal use of manpower resources.**

SCADA is designed for, and sized to, the pumping system it serves. The aim is the use of energy at minimal cost. An investment payback of less than two years is not uncommon, with ongoing energy-cost savings year after year.

SCADA, which can be effective in any size pumping system, can automate a few or multiple pumping-system operations, including scheduling, monitoring and controlling the use of energy for pumping applications. In an Energy Management System (EMS), pumps with lower operating costs are scheduled to operate first, ensuring energy and money savings.

In a small operation, SCADA might involve only on/off controls, such as time clocks or programmable controllers. For a large pumping system, a network of sophisticated computer controllers operates pumps as needed.

SCADA consists of a central control panel that controls the entire pumping system. An override feature allows authorized employees to vary the operating schedule at any time, if needed, or to make across-the-board adjustments to different areas.

Water Usage and Energy-Saving Ideas

You could reduce water and energy usage and save money by employing a variety of strategies, technologies and simple recommendations — from regular system recordkeeping to irrigation do's and don'ts. One or more of these approaches may go a long way to helping you manage your resource costs effectively.

Using Reservoir Storage

Taking longer to refill a reservoir may help you reduce water-production costs. Filling a reservoir can be accomplished by using one pump with a lower dollar per hundred cubic feet of water produced and pumping over a longer time period. Or you could fill it in a shorter time period using multiple pumps that have slightly higher cost values.

Even though the one-pump process may take more time and may only be possible in winter, the cost savings may be in your favor.

Using Reservoir Capacity

If you are on Time-of-Use (TOU) rates, you can reduce water-production costs during on-peak periods by using more of your reservoir storage capacity, instead of well pumps, to meet water demands.

You will need to make sure that lowering the water level will not cause damage to the reservoir coating. Recoating the reservoir to allow for lower water levels could prove to be cost-effective.

Using Priority Pumping

Priority pumping is a pumping-system strategy that has you select and decide which pumps to use first to achieve maximum water production at the least energy cost. And because using a priority-pumping program typically requires no capital investment, priority pumping may be a quick and effective way to save energy and money.

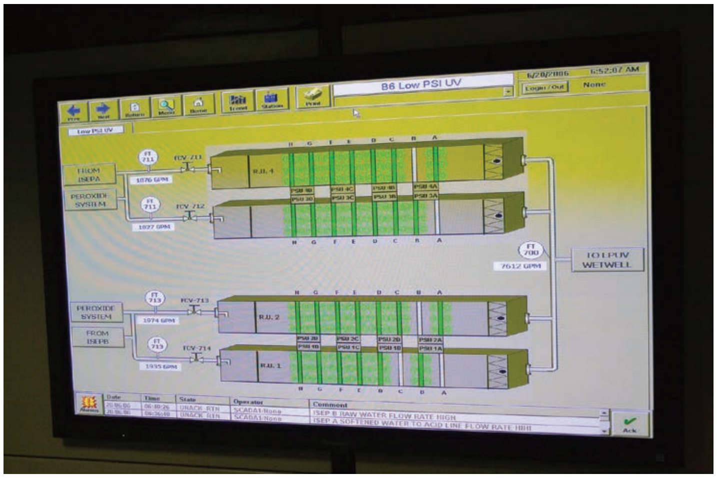
In order to know which pumps to use first and in which order, priority pumping requires that you know the water production characteristics of all your pumps beyond their performance efficiency. This information would include the following:

- Data on ground water level
- Discharge pressure
- Elevation
- Distance to the reservoir

A comparison of the resulting kWh/Acre Ft. for all pumps will help you determine what pumping-priority technique is best for your operation.

Not all water systems may be flexible or adaptable enough for priority pumping. Here are some conditions that may limit your efforts:

- Some well characteristics will limit how much a given pump can be used.
- Some pumps may be limited in ability to move water between given pressure zones. Possible restrictions on individual pump use may limit its performance.



Test Findings and Formulas We Use

Discharge Head: Observed discharge pressure, psi, multiplied by conversion factor of 2.31 feet/psi

Suction Head (Booster Applications): Observed suction pressure, psi, multiplied by conversion factor 2.31 feet/psi

Suction Lift (Booster Applications): Measured lift in feet or observed vacuum pressure gauge reading (Hg) multiplied by conversion factor 1.13 feet/psi

Total Head: (Wells) Discharge head plus pumping level (ft.)
(Boosters with positive suction) Discharge head minus suction head
(Boosters with Lift) Discharge head plus suction lift

GPM per Ft. Drawdown = $\frac{\text{GPM}}{\text{Drawdown, ft.}}$

Acre Ft. Pumped in 24 hours = $\frac{\text{GPM x 60 min./hr. x 24 hr.}}{\text{325,851 Gal./Acre Ft.}} = \frac{\text{GPM}}{226.3}$

Input kW (Electric Meter Timing): = $\frac{\text{Number of Meter Revolutions x 3.6 x Disk Constant x Meter Multiplier}}{\text{Time in Seconds for Meter Revolutions}}$

Meter Multiplier = The "MULT" value on meter face
Disk Constant = The "k_h" value on meter face

HP Input to Motor = kW input x 1.341

Water Horsepower = $\frac{\text{GPM x Total Head}}{3,960}$
(The output HP of Pump)

Motor Load (%) = $\frac{\text{HP input x Motor Efficiency in Percent}}{\text{Name Plate HP of Motor}}$

kWh per Acre Ft. = $\frac{\text{Input kW x 325,851 Gal. /Acre Ft.}}{\text{GPM x 60 min. /hr}} = \frac{\text{Input kW x 5,431}}{\text{GPM}}$

OPE (%) = (Water Horsepower / HP Input) x 100

Acidification: Injecting an acid chemical (usually hydrochloric acid or sulfuric acid) into a well to dissolve encrusted material on the casing perforations (slots).

Acre Foot: The quantity of water required to cover one acre of land (surface) with water one foot deep (325,851 gallons). The Acre Foot is the most common measure of volume in irrigated agriculture.

Adjustable Speed Drive: Drive speed at shaft adjusted either mechanically or electrically to control speed of pump. Refer to Variable Frequency Drive.

Air-line: A method of sounding a well. Small diameter tubing is installed to a known point below any expected pumping water level. The air pressure required to expel air from this tube indicated the water level in the well, either during pumping or at static conditions.

Application Rate (AR): Equivalent depth of water applied to a given area per hour by the system, usually measured in inches per hour.

Aquifer: A saturated water-bearing geological formation or group of formations having sufficient permeability to yield water to wells.

Axial Flow Pump: Pump design used for low-head, high flow conditions, also called a propeller pump.

Belt Drive: A device that transmits power from a driver (electric motor) to a pump by means of belts (either flat of V-belts) and pulleys.

Booster Pump: A pump used to lift or introduce water from a low surface level (reservoir, canal, lake, river, or pond) to a higher level or greater pressure of water system. This can be a horizontal or a turbine pump. In agricultural applications, Usually used for pumps supplying sprinkler, micro-irrigation system or water supply.

Bowl (Pump): The pump stage of a turbine pump. This is called the “volute” if referring to a centrifugal pump. It contains the rotating impeller and directs water flow into and out of the impeller.

Bowl Efficiency: Efficiency of the pump by itself (as opposed to combination of the pump driver and transmission system). It is difficult to determine bowl efficiency in the field. An estimation can be made by subtracting out other losses associated with the pumping plant such as the power plant and transmission efficiencies. Useful for initial specification or designing pump to match operational requirements.

Brake Horsepower (BHP): Brake horsepower is the output horsepower of a driver (electric motor) to a pump. It may also be used to refer to the required input horsepower to the pump itself.

Capacity (Pump): The flow rate of a pump. It is generally used when referring to the normal (or required design) flow rate of the pumping plant.

Capital Cost: The amount of money required to pay for the purchase and installation of a pumping plant.

Casing: Pipe used as lining for a well.

Cascading Water: Water entering the well at a point above the pumping water level. This can entrain air in the water and cause a significant loss of pumping efficiency. Cascading water may be an indication of an inefficient well or a signal of aquifer changes.

Cavitation: The rapid formation and collapse of air bubbles in water as it moves through a pump. This results from too high a vacuum in the pump itself due to insufficient “net positive suction head.” Cavitation causes pitting of the propeller and pump housing and can greatly degrade pump performance.

CCF: Hundred cubic feet.

CFS: Cubic feet per second is a rate of flow where large quantities of water are considered.

Centrifugal Pump: A pump in which water enters the center of a rotating impeller and is flung out radially, gaining energy in the process. This is also a term commonly used for a specific type of pump where the impeller is enclosed in a volute casing. A volute casing is a type of casing where the area of a water flow increases uniformly towards the pump discharge. The increase in flow area converts the velocity achieved through centrifugal action into pressure.

Check Valve: A valve installed in a pipeline that automatically closes and stops water from flowing backwards when a pump is shut off.

Chlorination: Periodic injection of chlorine compounds into wells to prevent the growth of bacteria and slimes. Also used when referring to injection into irrigation systems, most often micro-irrigation systems.

Column Loss: The value of head loss caused by flow friction in the well column pipe.

Column Pipe: The pipe that connects the bowl assembly of a turbine pump to the discharge head of the pump and conducts the water from the bowl assembly to the discharge head.

Concentric Reducer: A symmetrically-shaped pipe fitting used to constrict and divert flow from a larger to a smaller pipe.

Corrosion: Deterioration and destruction of metal by chemical and/or galvanic reactions. Chemical corrosion dissolves the metal, which is then carried away by the water. Chemical corrosion can allow sand to enter the well. Galvanic corrosion is caused by electrolytic cells forming between dissimilar metals or surfaces.

Daily Crop Water Use (Evapotranspiration): This is the net amount of water extracted from the soil daily by the crop and surface evaporation from the soil.

Deep-Well Turbine Pump: A turbine pump installed inside a well casing below the pumping water level in the well.

Development of Well: The process of removing the finer material from the aquifer or gravel pack surrounding a well, which may include drilling mud forced into the formation during well construction. If performed after the well has been in service for some time it is referred to as “re-developing” a well.

Discharge Pressure: Pressure at the discharge flange of a pump.

Discharge Head: A measurement of pressure, in feet of head, at the discharge flange of a pump. A discharge head can also be a physical part of a turbine-type pump base, which supports the column pipe and bowl assembly of a turbine pump.

Distribution Uniformity (DU): A measure of how evenly water soaks into the field during irrigation. It is usually a percentage between 0 and 100; the higher the number the better. A DU of 100% is theoretically possible but practically impossible to achieve. It is the upper limit of irrigation efficiency if the whole field is sufficiently irrigated.

Drawdown: The difference in elevation between static and pumping water levels in a well, usually following a specified operating time.

Driven: A machine or piece of equipment (pump) that requires power from a prime mover (motor) such as a motor-driven pump.

Driver: A prime mover (motor) that supplies power to a machine (pump), generally either a windmill, an electric motor, or an internal combustion engine.

Driver Efficiency: The ratio of the driver output to the power input. Typically expressed in percent efficiency.

Dynamic Head: The sum of pressure and pumping head developed by a pump.

Eccentric Reducer: A non-symmetrically-shaped pipe fitting used to constrict and divert flow to a smaller pipe without leaving an air space at the top of the large pipe.

Effective Root Zone: The depth of soil in which you are actively managing the crop (fertilizer levels, tilth, soil moisture, etc.).

Electric Motor: A device that converts electrical energy to mechanical work.

Electrical Sounding Probe: Device used to measure water level in a well by completing an electrical circuit when a probe is lowered into the well water.

Encrustation: The accumulation of material in the perforations of the well casing, in well screen openings, and in the voids of gravel pack and water-bearing soil. Encrustation decreases open areas in the well casing, impedes water flow into the well, and decreases well efficiency.

End Seal: A seal on the bottom end of the impeller in a turbine pump bowl assembly.

Entrained Air: A mixture of small air bubbles within water. It can develop due to vortexing (whirlpools that form at a pump intake) or cascading water into a well. Entrained air in a pumping system displaces water from the impeller and reduces pump capacity and efficiency.

Evapotranspiration: See “Daily Crop Water Use”

Feet of Head: Feet of head is a measure of pressure in a water system (1 foot of head= 0.433 psi).

Field Capacity: The amount of water the soil will hold.

Float Switch: An electrical switch in the control circuit of a motor control that is actuated by a float in a water tank or reservoir.

Flow Meter: Any measuring device used to measure fluid flow rates in a pipe or open channel. The flow meter may measure instantaneous flow rates or total fluid volumes over a period of time.

Freeboard: Distance from the top of the flowing water to the top of the channel banks.

Friction Head: The head in feet required to overcome the fluid friction in a pipe or water system.

Friction Losses: Energy losses associated with moving water against rough surfaces. In water pumping applications it is the water pressure lost as a result of contact between moving water and the enclosure that it is moving in (either a pipeline or open channel).

Gal/Min. (GPM): Gallons per minute – a rate of flow.

Gas Engine: An internal combustion engine using gasoline or propane as fuel.

Gate Valve: A valve commonly utilized to control flow by lifting or closing a gate. All gate valves have a rising or a nonrising stem. Rising stems provide a visual indication of valve position. Nonrising stems are used where vertical space is limited or underground.

Gear Drive: A mechanical device using gears to connect a driver to a pump. Commonly they are used either to provide different pump speeds or to connect an internal combustion engine to a well pump.

Gravel Pack: A thin layer of various sizes of gravel placed between the well casing and the well itself. Gravel packs are designed to prevent soil particles from entering the well casing.

Head (Water Head): An alternative term for pressure. One pound per square inch pressure (1 psi) equals 2.31 feet of water head. That is, a column of water 2.31 feet high will exert 1 psi at the bottom of the column.

Head-Capacity Curve: A pump performance curve of a particular impeller type showing the relation of dynamic head and flow rate.

Horsepower (HP): Horsepower is a rate of doing work- how far can a mass be moved in a period of time. One horsepower equals 33,000 foot pounds per minute, that is, one horsepower can raise 33,000 pounds one foot over the period of one minute.

Impeller: The impeller is the rotating component of the pump and is contained within the pump bowl (or pump volute). Impellers may be figured as open, closed, or semi-open. They are usually made of bronze, cast iron, plastic, or cast iron coated with porcelain enamel. The impeller transfers energy developed by the pump driver to the water as water flows through the pump bowl.

Impeller Trim: The specific diameter of the impeller used in a pump. Impellers are cast at the maximum diameter but may be "trimmed" to better match the required operating condition(s).

Induction Motor: A type of electric motor commonly used on pumps.

Input Horsepower: The horsepower input to a pumping plant. Value can be calculated from electrical, diesel, or propane power using standard conversion factors.

Irrigation Efficiency (IE): A measure of how much water that is pumped and applied to a field is beneficially used. (Beneficial uses include crop water use and leaching for salt control.) One must know the physical and time boundaries of the measurement for it to be meaningful. The IE for a single irrigation on a field may be different than the average IE for all irrigations on that field for a season. It may be different than the IE for the entire farm for the season. It is usually expressed as a percentage between 0 and 100. An IE of 100% is not theoretically possible due to immediate evaporation of water during irrigation.

Kilowatt: A unit of electrical power. 1000 watts

Kilowatt-hour (kWh): The amount of energy expended by a one kilowatt device over the course of one hour.

Line Shaft: A shaft used to connect a motor to the impeller(s) of a turbine pump.

Line Shaft Bearing: A bearing used on the line shaft of a turbine pump.

Line Shaft Loss: Is the power, expressed in horsepower, (kW), required due to the rotation friction of the line shaft. This value is added to the bowl assembly input to predict the pump input.

Manometer: A portable device using what is known as velocity head (the energy of the moving water) to measure water flow rates in pipelines. These are commonly used during pump efficiency tests due to the ease of installation and removal. However, they are large and require careful handling and are not generally recommended for use by pump owners.

Megohmmeter: An instrument for measuring electric motor insulation resistance.

Motor: A rotating machine that converts electrical power (either alternating current or direct current) into mechanical power.

Motor Load: The output horsepower of an electric motor divided by the rated horsepower of the motor as a percent. This should generally be between 80 and 115 percent.

Multi-Condition Pump Test: A pump efficiency test where pump performance is measured at various Total Head and capacity conditions. Three points are typically taken by throttling discharge valve. Can be used to determine pump's best efficiency point and as a comparison to pump performance curve.

Multi-Stage Pump: A pump having more than one impeller/bowl assembly. Commonly used when referring to turbine pumps.

Net Positive Suction Head (NPSH): A design requirement dependent on the individual pump. The required NPSH must be available at the pump inlet to prevent cavitation.

Net Water Needed Versus Gross Water Applied: Net water is what you need to replace in the field. Gross water is how much you have to pump in order to accomplish this goal.

Oil Tubing: In a turbine pump, the oil tubing encloses the line shaft of the pump giving it rigid, vibration-free support. It extends from the top of the bowl assembly in the well to the pump discharge head at the ground level.

Operating Condition: The combination of flow and pressure (total dynamic head) developed by the pump. A pump can operate at a number of operating conditions defined by its pump performance curve.

Operating Cost: The sum of the expenses necessary to keep a pumping plant in operation. It includes the cost of energy, lubricating oil, maintenance, repairs and labor.

Overall Pumping Plant Efficiency (OPE): A measure of how much water horsepower is produced by the pumping plant from the input horsepower. It is the combination of three efficiencies;

- Bowl efficiency – the efficiency of the pump itself.
- Driver efficiency – the efficiency of the electric motor or engine.
- Transmission efficiency – a measure of losses that occur in transmission shafts, chains, pulleys, and v-belts.

Packing: A flexible material which can be compressed around a pump shaft (between the rotating shaft and the pump case) to prevent leakage of the fluid being pumped.

Parallel Pumps: Two or more pumps (many times of different sizes for flexibility) discharging into a common pipeline to increase the flow rate at a given pressure in the pipeline. Common for booster stations in municipal applications in which varying demand signals pumps to turn on or off.

Pressure Switch: An electric switch in the control circuit of a pump motor that is actuated by the pressure of the water in a water system.

psi: Pounds per square inch is a measure of pressure in a water system. A vertical column of water 2.31 feet high will exert a pressure of one pound per square inch.

Pump: A mechanical device that converts mechanical energy (usually a rotating shaft or reciprocating rod) into a hydraulic energy (flowing water for example).

Pump Capacity (see, Capacity (Pump))

Pump Case: The body of a pump that encloses the impeller and directs the flow of water from the suction to the discharge of the pump.

Pump Curve: A graph that illustrates the performance of a pump from zero to maximum capacity. It will also indicate the head and the horsepower of the pump.

Pump Discharge: The point at which water is discharged from a pump or a pump base. Also can be referred to as Discharge Head.

Pump Efficiency Test: A series of measurements and calculations providing information concerning performance of the pump (and of the well if applicable). The test will indicate the overall pumping plant efficiency, pump flow rate, required pump input horsepower, and discharge pressure among other things.

Pump Performance Curve: A set of measurements, usually in graphical form, available from the pump manufacturer showing the relationship between Total Head, horsepower requirements, and net positive suction head requirements at any given flow rate for a pump.

Pumping Head: The difference in elevation between the pump water level and the pump discharge.

Pumping Lift: The distance from the center line of the discharge pipe at the pump head to the water level in the pumping well.

Pumping Water Level: The elevation of the water level in a well during pumping.

Radial Bearing: One of the two bearings in a vertical electrical motor.

Revolutions Per Minute (RPM): The rotating shaft of a pump or the driver (motor).

Sand Separator: A device installed on the pump intake pipe in deep-well turbine pumps to remove sand from the water before it can enter the pump. They may also be installed on the pump outlet works and be used to remove sand in water before it enters water distribution systems (municipal, industrial, and irrigation).

Semi-Open (Semi-Closed, Mixed Flow) Impeller: An impeller design whereby water enters the eye of the impeller and exits at less than a 90 degree angle. Another defining characteristic is that the impeller is closed on only one side of the vanes. The pump bowl constrains the water flow on the other side.

Series Pumps: Two or more pumps installed so that one pump discharges into the intake of another pump, increasing pressure at a given flow rate. The Total Head developed by the second pump is added to the Total Head of the first pump. The most common configuration is a well pump discharging into a booster pump. Note also that a "multi-stage" turbine pump is actually a pump connected in series.

Shaft (Pump): The round bar to which the impeller of the pump is fastened. It transmits the rotational energy of the driver to the impeller.

Soil Moisture Depletion (SMD): The net amount of water that you need to replace in the root zone of the crop.

Soil Probe: A long piece of 3/8" steel bar, usually tipped by a ball bearing, with a handle. The probe is pressed into wetted soil to judge how deep water has penetrated. It can be used during an irrigation to indicate when enough water has soaked into the ground. It can also be used to judge the uniformity of an irrigation. If 2-3 days after an irrigation the probe can be pushed into the soil to a depth of 4 feet at the top of a furrow, and only to 2 feet at the bottom of the same furrow, this is an indication of poor distribution uniformity.

Sounding a Well: The process of determining where the water level is in a well. This might be the static water level (no pumping) or the pumping water level.

Sounding Tube: A small pipe extending from above the foundation or grout seal into the well casing to allow access for sounding the well.

Stage (Pump): One impeller/bowl assembly of a turbine pump. Pumps can be termed as "single-stage" or "multi-stage" pumps.

Static or Standing Water Level: The elevation of the water level in a well at rest (Pump Off). Time for stabilization varies from several minutes to several days.

Straightening Vanes: Metal strips attached to the inside of a pipe that straighten out the flow of turbulent water usually to provide a more symmetrical flow profile when measuring flow rates.

Suction Bell: A bell-shaped fixture placed on the suction intake of pumps to decrease energy losses.

Suction Lift (Suction Head): Distance from the water surface to the pump intake when the pump is located above the water surface.

Submersible Pump: A type of deep-well turbine pump which utilizes a waterproof electric motor that is connected directly to a turbine pump, both being installed in the well below the pumping water level.

Surging: Fluctuating flow of water from a pump that is created as the pump attempts to pump more water than is flowing into the pump. As applied to a well it occurs when the pump is moving more water than is flowing into the well. This causes the pumping level to drop to the pump intake, breaking the intake suction and allowing a lug of air to enter the pump. The pump capacity falls and the well water level begins to rise. Water then re-enters the pump and the pump flow increases, causing the cycle to repeat, creating a surging action.

Tailwater Reuse/Return System: A system used in surface irrigation to recover and reuse irrigation runoff.

Test Suction: The section of pipe or open channel where flow measurements are taken.

Testing of Wells: The process of determining the drawdown and yield performance of a well.

Thrust Bearing: The bearing in the turbine pump discharge head of in the vertical hollow shaft motor that supports the vertical downward thrust of the turbine pump.

Time-of-Use Rates (TOU): Electric power rate schedules whereby lower costs are offered for power used in the "off-peak" (and sometimes during the "shoulder" or "mid-peak") period and higher rates are charged for power used during "on-peak" periods. The term "on-peak" refers to times when power use is the highest for a utility. Conversely, off-peak refers to that time when power is lowest.

Totalizer: A type of flow meter, or part of a flow meter, that provides a measure of total water volume flowing past a point over time.

Total Dynamic Head (TDH): Defined as the total dynamic discharge head minus the total suction head or plus the total dynamic suction lift. The pressure in a pump at the impeller outlet (last impeller if there are pumps in a series). This pressure is available to lift water to the soil surface (if in a well), to overcome pressure losses caused by friction and elevation differences, and to provide the required operating pressure in the system. Note that 2.31 feet of head equals one-pound-per-square-inch (psi) of pressure.

Turbine Pump: A centrifugal-type pump with a vertical shaft. The bowls are small in diameter so that they can be installed in a well of any depth (from a few feet to more than 1,000 feet). Many times, multiple pump assemblies (pump bowl and impeller) are stacked on top of each other and the water is directed by the pump bowl upwards to the next impeller/bowl assembly to match system demand.

Variable Frequency (Speed) Drive (VFD): A solid-state electrical device used to change the frequency of AC electric energy supplied to an electric motor. Varying the frequency of the AC current will vary the speed of the motor. VFDs are used in situations requiring many different operating conditions on a regular basis.

VHS Motor: A vertical hollow shaft motor. It is a type of vertical induction motor with a hollow motor rotor.

Vortex: A whirlpool leading into the pump inlet. These are undesirable as they generally entrain air. They are caused by insufficient submergence of the pump intake or poor design of the pump intake works.

Voltage: The electromotive force that causes electrons to move through a circuit.

Water Horsepower (WHP): The output horsepower of a water pump. It is the combination of flow rate and pressure. And,

WHP = Flow x TDH / 3960

Where: Flow is the pump flow rate in gallons per minute and TDH is total dynamic head in feet of water head at that flow rate.

Water Level: The distance in feet between the ground level and the water surface in a well. For pump testing purposes it is the vertical distance between the center line of discharge head to water surface in well.

Watt: A unit of electrical power.

Wear Ring: A part of a centrifugal pump that provides a water seal between the impeller and the pump case (or bowl of a turbine pump). It seals the high pressure side of the impeller from the low pressure (suction) side.

Well Casing: Pipe (usually some type of metal but may also be plastic) used as the lining for a well. A layer of rock (termed the "gravel pack") usually placed between the well casing and the aquifer to help prevent soil particles from entering the well. The casing will have small openings (called perforations or slots) at levels where water-bearing soil formations are thought to be.

Well-Efficiency: The drawdown outside the well casing divided by the drawdown inside the well (the higher the number the better).

Well-Specific Capacity: Expressed in US gallons per minute per foot of drawdown (liters per second per meter of drawdown). It is the rate of flow being pumped from the well divided by the total drawdown as measured during test conditions.

Conversions and Affinity Laws

Pressure (Head)

1 Atmosphere	14.70 Pounds per Square Inch 34 Feet of Water 10.4 Meters Of Water
1 Pound per Square Inch	2.31 Feet of Water Head 6.9 Kilopascals 2.04 Inches of Mercury 0.703 Kilogram per Square Centimeter
1 Foot of Water Head	0.433 Pounds per Square Inch 0.883 Inch Mercury
1 Kilogram per Square Centimeter	14.2 Pounds per Square Inch
1 Inch of Mercury (vacuum)	1.13 Feet of Water

Flow Rate(Capacity)

1 Cubic Foot per Second	448.8 Gallons per Minute
1 Liter per Second	15.85 Gallons per Minute
1 Acre Inch per Hour	452.6 Gallons per Minute
1 Cubic Meter per Minute	264.2 Gallons per Minute
1,000,000 Gallons per Day	694.4 Gallons per Minute
1,000 Gallons per 24 Hours	1.44 Gallons per Minute

Volume

1 U.S. Gallon	3.785 Liters 231 Cubic Inches 0.1337 Cubic Feet 0.00379 Cubic Meters
1 Cubic Foot	7.4805 Gallons (U.S.) 0.0283 Cubic Meter
1 Liter	0.2642 Gallons (U.S.)
1 Barrel	42 Gallons (U.S.)
1 Acre Foot	325,851 Gallons (U.S.) 43,560 Cubic Feet
1 Acre Inch	3,630 Cubic Feet 27,154 Gallons (U.S.)
1 Cubic Meter	264.2 Gallons (U.S.) 35.3 Cubic Feet
1 Cubic Centimeter	0.06102 Cubic Inch
1 Cubic Inch	16.39 Cubic Centimeters

Length

1 Inch	2.54 Centimeters
1 Mile	5,280 Feet 1,609 Meters 1.609 Kilometers
1 Foot	0.3048 Meter

Mass

1 Pound	0.4536 Kilograms
1 Long Ton	2,240 Pounds
1 Short Ton	2,000 Pounds

Weight of Water Volumes

1 U.S. Gallon of Water	8.345 Pounds
1 Cubic Foot of Water	62.4 Pounds
1 Kilogram or Liter of Water	2.2 Pounds

Power

1 Kilowatt	1.341 Horsepower 0.102 Boiler Horsepower
1 Kilowatt Hour	3,413 British Thermal Units (btu) per Hour
1 Horsepower	0.746 Kilowatts 33,000 Foot Pounds per Minute 2,545 British Thermal Units (btu) per Hour

Affinity Laws

(used for variable speed pumping energy calculations)

Impeller diameter held constant

1) $$\frac{Q_2}{Q_1} = \frac{N_2}{N_1}$$

Where

Q = Capacity (GPM)
N = Speed (RPM)
H = Head (feet)
BHP = Brake Horsepower

Example:

$$\frac{1{,}000\ \text{GPM}}{1{,}200\ \text{GPM}} = \frac{1{,}500\ \text{RPM}}{1{,}800\ \text{RPM}}$$

2) $$\frac{H_2}{H_1} = \left[\frac{N_2}{N_1}\right]^2$$

Example:

$$\frac{100\ \text{feet}}{144\ \text{feet}} = \left[\frac{1{,}500\ \text{RPM}}{1{,}800\ \text{RPM}}\right]^2$$

3) $$\frac{BHP_2}{BHP_1} = \left[\frac{N_2}{N_1}\right]^3$$

Example:

$$\frac{32.0\ \text{BHP}}{55.3\ \text{BHP}} = \left[\frac{1{,}500\ \text{RPM}}{1{,}800\ \text{RPM}}\right]^3$$

Note: Some caution must be exercised when using the affinity laws. If performance curves are available for the pump from the manufacturer or from actual test results, they should be used to obtain all necessary information. The affinity laws apply only tocentrifugal pumps.

Energy Efficiency Information and Incentives

SCE's Energy Efficiency Solutions
sce.com/solutions or call **1-800-736-4777**

U.S. Department of Energy's Best Practices Web Page
https://www.energy.gov/eere/femp/downloads/operations-and-maintenance-best-practices-guide

Pump Test Requests

There are three ways to request a pump test.

1. Call one of the numbers below depending on your plant location:
   - L.A. Area, Orange County, San Bernardino County — 1-800-634-9175
   - San Joaquin Valley — 1-800-634-9175
2. Please email us at HydraulicServices-Pumptest@sce.com.
3. Contact your assigned SCE account manager.

NR-609-R4-1118

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