EVALUATION OF WATER PUMPING SYSTEMS

Calculation Sheet Guide

First Edition

Water and Sanitation Intiative

Sustainable Energy and Climate Change Initiative

Inter-American Development Bank

EVALUATION OF WATER PUMPING SYSTEMS

Calculation Sheet Guide

First Edition

Water and Sanitation Initiative
Sustainable Energy and Climate Change Initiative
Washington, D.C.
2011

For further information please contact: agua@iadb.org or secci@iadb.org

IDB-MG-114

CONTENTS

PRESENTATION

As part of its Technical Cooperation "Energy Efficiency for Caribbean Water and Sanitation Companies," the Sustainable Energy and Climate Change Initiative (SECCI) of the Inter-American Development Bank (IDB) financed the development of a regional methodology to improve energy efficiency and maintenance of water companies in Latin American and Caribbean countries. This methodology, developed by the consulting firms Econoler International and Alliance to Save Energy, focuses mainly on electromechanical efficiencies of water pumping systems in the Caribbean. This publication presents a guide to the calculation sheet. The calculation sheet, an energy efficiency assessment manual, and a maintenance manual for the evaluation of the systems are also available on the IDB Publications Portal: http://www.iadb.org/publications/ and the Water and Sanitation Initiative Portal: http://www.iadb.org/en/topics/water-sanitation/energy-efficiency-for-utilities,4492.html.

The following people from the Sustainable Energy and Climate Change Unit (ECC) and the Water and Sanitation Division (WSA) supervised the preparation of this manual: Christoph Tagwerker (ECC), Marcello Basani (WSA), Rodrigo Riquelme (WSA), and Gerhard Knoll (WSA). Econoler International and Alliance to Save Energy developed the manual – Arturo Pedraza and Ramón Rosas.

Water and Sanitation Initiative
Sustainable Energy and Climate Change Initiative

INTRODUCTION

Efficiency improvements in municipal water utilities are worthwhile investments, because of their impressive yields in the form of operational and overhead savings, superior service, and improved financial sustainability.

In addition, in a sector that requires constant infrastructure upgrades and adjustments in operational needs, improvements in energy and water efficiency, when applied within an integrated planning process, can defer—and in some cases eliminate—the need for additional infrastructure investment.

By following a consistent methodology, energy efficiency evaluations apply a set of techniques to determine the degree of efficiency with which energy is used, and specify the amount of wasted energy.

This manual details a sequence of activities to achieve better results for successful energy efficiency evaluations. Conclusions drawn from such evaluations include the identification and quantification of low-cost measures or profitable investments for saving energy through new installations, and lead to the further development of a comprehensive energy efficiency project.

Energy assessments in water supply and sanitation systems should include an analysis of the principal elements that consume energy based on the distribution of energy losses, namely:

- Motor and pump assembly, including efficiencies, operating conditions, and maintenance aspects.
- Distribution systems, including pipes, regulation tanks, and other accessories.
- Electromotive systems, including transformers.
- Power supply systems, including the characteristics of the supply contract.

The proposed methodology is focused on the following typical energy efficiency measures:

- Power factor optimization.
- Pump optimization.
- Use of high-efficiency motors.
- Reduction of pressure losses in pipes.
- Selection of the optimal size of conductors.

Other opportunities for energy savings that can result from this type of analysis include tariff adjustment; changes in the operating schedule to avoid expensive peak hour energy consumption; on-site power generation, especially during peak hours; application of variable speed drives; and optimization of hydraulic operation.

This manual describes the methodology for performing the calculations during the energy efficiency evaluation of a pumping system, and includes a step-by-step methodology in a separate spreadsheet.

Note: The spreadsheet contains example data. The actual template will have the following: YELLOW fields: cells that need to be REPLACED or FILLED IN with the utility's actual pumping system information; and GREEN FIELDS: cells that WILL BE CALCULATED AUTOMATICALLY. We strongly recommend saving the spreadsheet in a file with the name of the corresponding pumping system before filling it in.

OBJECTIVE

This methodology aims to evaluate a pumping system through an energy balance, and to suggest energy saving measures to improve the system.

The formulas that are used are related to units of measure described in each point, so special attention must be paid to the respective units in the format. If data are available in other units, they need to be previously converted into the specified units for the formulas to function properly.

HEADER DATA

Data must be placed in the header as follows:

Site – place or region of the equipment under study.

Date – date of which the measurements and the study of the pumping system are performed.

Agency – company, corporation, or utility responsible for the operation of the pumping system.

System – hydraulic system to which the pumping system belongs; enter parent/subsystem if applicable.

Equipment – name of equipment.

ENERGY AUDIT OF PUMPING SYSTEM

Once the header information is complete, please fill in the remaining part of the form using the steps below.

SITE: South plain. **DATE:** 14-Aug-2009

AGENCY:	Water and Sewage of the North (WSN)		
SYSTEM:	South East-Plains	**EQUIPMENT:**	Deep Well PP 14

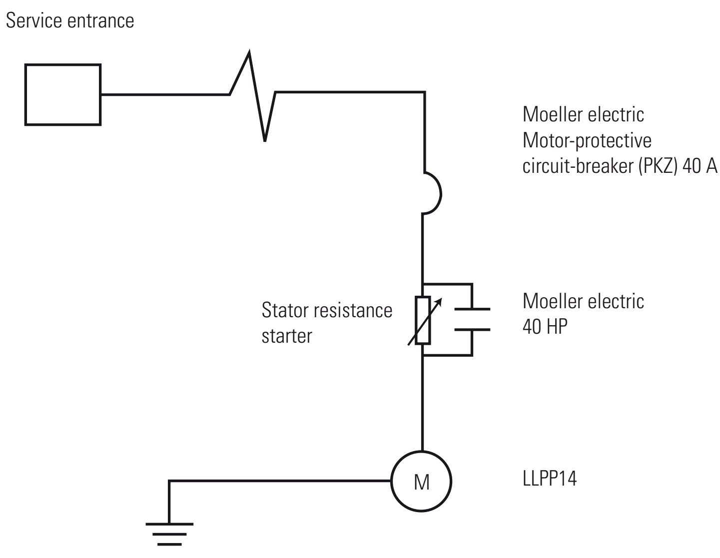
STEP 1. GATHER DATA

1.1 ELECTRICAL SYSTEM

In this section, provide the data for the electrical system.

ELECTRICAL DIAGRAM: Outline the unifilar diagram connections of the electrical equipment, intake, cabling, transformer, main switch, and starter, if applicable.

Example:



POWER SUPPLY: Enter the information about the provider of electrical service and details of the contract with this company.

Example:

POWER SUPPLY	
Supplier:	NEC BS
Service No:	D-3364605
Contract tariff:	3

Supplier – name of the electric company.
Service No. – the contract number on the receipt or electrical invoice for this pumping system.
Contract tariff – the key or name of the fare schedule in the contract.

TRANSFORMER: Fill in the information regarding the type, capacity, and rated voltage.

Example:

TRANSFORMER	
Type:	Pole-mounted three phase
Capacity:	3 x 25 kVA
Rated voltage:	13,800 / 440 V

Type – type of transformer that feeds the electrical equipment; if appropriate, denote DIRECT SUPPLY in the legend.
Capacity – the capacity of the transformer; if supply comes from more than one transformer, enter the capacity (kVA) for each of them.
Rated Voltage – the input and output voltage of the transformer (V), separated by a forward slash; if the transformer has more than one output voltage, enter the real voltage (the voltage at which the transformer is currently operating).

MAIN SWITCH: Fill in the data for the main switch of the equipment, which is the energy source for the transformer or equipment.

Example:

MAIN SWITCH	
Make:	Moeller Electric
Capacity:	40A
Setting:	32–40A

Make – brand or manufacturer of the switch.
Capacity – the nominal capacity of the switch (A).
Setting – if the switch is an adjustable type, enter the nominal capacity where the switch is set (A).

STARTER: Enter the information regarding the type and capacity of the motor starter, if applicable.

Example:

STARTER	
Type:	Stator Resistance Starter
Capacity:	40 HP

Type – starter type.
Capacity – starter capacity (HP).

PROTECTION: Enter the information regarding the starter motor overload protection data.

Example:

PROTECTION	
Make:	Moeller Electric
Capacity:	32–40A
Setting:	37 A

Make – manufacturer of the thermo-magnetic element of the motor's protection.
Capacity – capacity of the thermo-magnetic element of the motor's protection (A).
Setting – setting point of the thermo-magnetic element (A).

CAPACITORS: If applicable, denote the total capacity of the capacitor bank (kVAr).

Example:

CAPACITORS	
Capacity:	kvar

Grounding System: Circle the corresponding box for each answer, and write the caliber of the cable connected to the ground for each described element.

Example:

GROUNDING SYSTEM				
Is there a grounding system?	YES	NO		
Separated neutral and ground?	YES	NO		
Grounded transformed?	YES	NO	Caliber:	
Grounded starter?	YES	NO	Caliber:	6
Grounded motor?	YES	NO	Caliber:	

Conductors: Fill in the data related to the size and length of conductors in two branches. The first goes from the service supply (either a transformer or a direct supply) to the starter or main switch. The second branch goes from the starter or main switch to the motor.

Example:

CONDUCTORS	
Service Entrance – Starter	
Caliber:	10 mm^2
Length:	15 m
Grouping:	
Starter – Motor	
Caliber:	12 AWG
Length:	53 m
Grouping:	3W / Conduit

Caliber – the caliber of the electric conductor (mm^2) or in American Wire Gauge (AWG); write the data stamped on the lining of the cable.
Length – the total length of conductors in the described stretch (m).
Grouping – describes how the conductors are grouped.

OBSERVATIONS: Describe any specific situation that will allow for a better understanding of the equipment's electrical system.

OBSERVATIONS:	

1.2 NOMINAL MOTOR DATA

In this section, provide the nominal data of the electric motor and the maintenance history of the equipment.

NAME PLATE DATA: Fill in the information from the motor plate; if the plate is unreadable, refer to the purchase order or document describing the characteristics of the motor.

Example:

NAMEPLATE DATA					
Make:	Grundfos	**Voltage:**	440 V	**Type:**	Submersible
Capacity:	10 HP	**Current:**	15.0 A	**Frame:**	
Speed:	3,450 RPM	**Efficiency:**	79.0%	**SF:**	0.85

Make – brand or manufacturer of the motor.
Capacity – nominal capacity of the motor (HP).
Speed – angular speed of the motor (RPM).
Voltage – nominal voltage of the motor (V).

Current – nominal current of the motor (A).
Efficiency – nominal efficiency of the motor (–).
Type – motor type.
Frame – frame type or number of the motor's frame.
SF – found on the motor plate; when not shown on the plate, the SF should equal one (1). This factor indicates the motor overload ratio. A factor of more than one indicates that the motor can withstand such overload.

HISTORY: Enter the motor maintenance history; data of interest for an energy audit of the equipment.

Example:

HISTORY					
Age:	1 years	**No. of rewindings:**	0	**Operation:**	8,760 hrs/year
OBSERVATIONS:	The motor has been overloaded and stopped five times this year for a period of 2 hours				

Age – number of years the motor has been in use since its first installation.
Operation – average of the motor working hours per year (hrs/year).
No. of rewindings – total number of rewindings that have been made to the motor since its first installation.

OBSERVATIONS: Provide any significant details relating to the motor's maintenance and changes in parts and/or operation.

Example:

OBSERVATIONS:	The motor has been overloaded and stopped five times this year for a period of 2 hours.

1.3 NOMINAL PUMP DATA

In this section, describe the nominal data or design of the pump. If field data are not available or the plate of the pump is unreadable, refer to the documents supplied with the pump at the time of purchase.

FRAME: Fill in the data concerning the body of the pump.

Example:

FRAME	
Make:	Grundfos
Type:	Submersible
Model:	Sp 45-4N
Age:	years

Make – brand or manufacturer of the pump.
Type – examples include submersible, turbine vertical, horizontal, centrifugal, and so on.

Model – pump model, according to the manufacturer.
Age – number of years that the equipment has been in operation since its installation.

IMPELLER – Provide data about the impeller of the pump.

Example:

IMPELLER	
Type:	Closed
Material:	SS
Diameter:	m
Age:	1 years

Type – driving pump type.
Material – impeller material.
Diameter – nominal diameter of the impeller.
Age – number of years that the impeller has been in operation. If the impeller has been changed over the life of the pump, its age might differ from that of the pump.

SHAFT: Fill in the data of the transmission shaft between the motor and pump.

Example:

SHAFT:	**Diameter:** in.	**Length:** m

Diameter – diameter of the shaft (inches).
Length – total length of the shaft (m).

DESIGN DATA: Most manufacturers' models describe these design features based on the optimal operation of the characteristic curve of the pump.

Example:

DESIGN DATA:	**Design Head:** 22 m	**Design Flow:** 18.61 l/s

Design pressure – design load or head (m).
Flow capacity – design flow (l/s).

OBSERVATIONS – Provide any significant details relating to the pump's maintenance and changes in parts and/or operation.

Example:

OBSERVATIONS:	The pump has been stopped for 24 hours. There are no records of the pump's age

1.4 FLUID CHARACTERISTICS

In this section, specify the main characteristics (only) of the pumped fluid. These characteristics will vary depending on whether the water is sewage or potable.

Example:

Fluid:	Water	**Temp.:**	24 °C	**Density:**	1000 kg/m^3
OBSERVATIONS					

Fluid – description of the type of fluid, such as raw water, treated water, or sewage water.
Temp – operating temperature of the fluid (ºC).
Density – density of the pumping fluid (kg/m^3).
Observations – Describe any particular conditions of the pumped fluid.

Once these data are collected, the first step of the energy audit is complete.

STEP 2. FIELD MEASUREMENTS

In the second step of this methodology, field measurements must be collected, including water parameters, electrical parameters, and temperatures.

2.1 HYDRAULIC MEASUREMENTS

Hydraulic parameter measurements are used to obtain pressures, flows, and levels.

LEVELS: Measure the vertical working levels of the pumping equipment to get a correct interpretation of the results of efficiency.

Example:

LEVELS			
Tank suction level (A):	32.4 m	**Suction pipe length (B):**	39.95 m
Distance of discharge pressure gauge (C):	0.28 m	**Height of gauge (D):**	0.98 m

Reference level: First of all, define the reference level (datum). All vertical measurements will be made in relation to this reference level, which differs based on the pumping system.

- **Deep wells –** the well head (the point where a probe can be inserted).
- **Pumping stations –** pump support (see figure).
- **Booster pumping systems –** level of reference can be the floor level or the center of the suction pipe (see figure).

Tank suction level (A): Measure the vertical distance in meters (m) between the water level and the reference level, according to the type of pumping system.

- **Deep wells –** distance between the dynamic level and the reference level (see figure).
- **Pumping stations –** distance between the water level and the reference level (see figure).
- **Booster pumping systems –** substitute the suction reservoir level for the level of the manometer suction, and measure the distance between the reference level (Nr) and the center of the manometer suction (see figure).

Suction pipe length (B): Measure the length of the pipe from the suction point of the pump to the discharge head of the pump in meters (m), according to the type of pumping system.

- **Deep wells –** if the pump is submersible, use the distance between the pump and the discharge elbow in the well head; if the pump type is a vertical turbine, use the distance between the impeller and output in the well head (see the corresponding figure).
- **Pumping stations –** distance or pipe length from the top of water up to the level of the floor (see the corresponding figure).
- **Booster pumping systems –** in this case, the length will be zero (0).

Distance of discharge pressure gauge (C): Measure the distance between the discharge point of the head of the pump and the discharge pressure gauge in meters (m), according to the type of pumping system (see corresponding figure).

- **Deep wells –** in a submersible pump, use the distance between the output pipeline and pressure gauge; in a turbine pump, use the distance between the start of the discharge pipe and the pressure gauge point.
- **Pumping stations –** distance between the point of the pump discharge and pressure gauge.
- **Booster pumping systems –** in this case, the length will be zero (0).

Height of gauge (D): Measure the distance between the reference level and the discharge gauge in meters (m) (see the corresponding figures).

FIGURE 1 Deep Wells

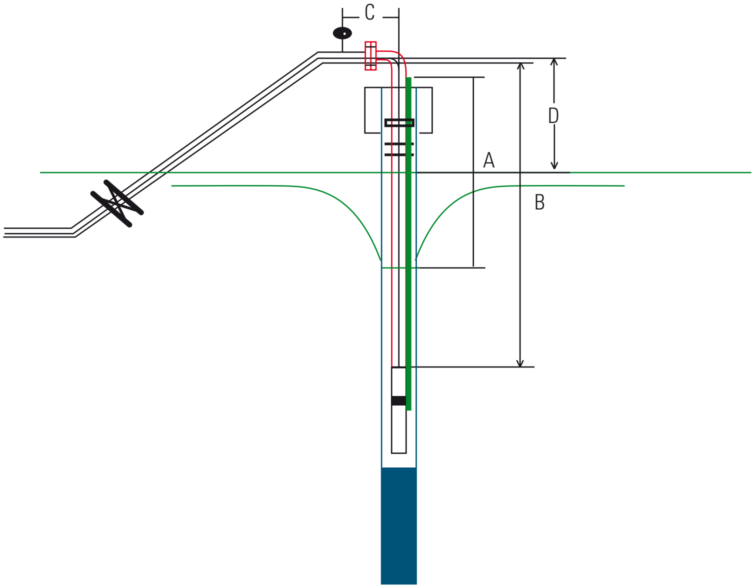


FIGURE 2 Pumping Stations

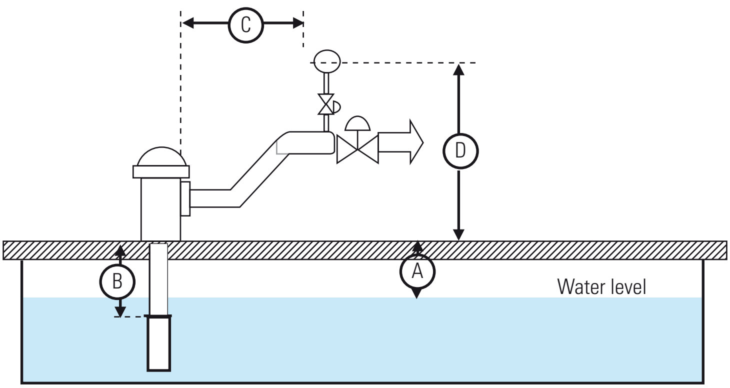
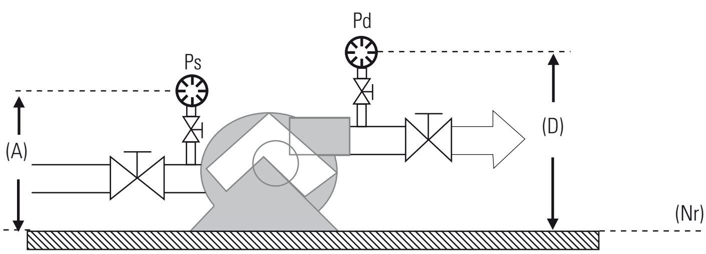


FIGURE 3 Booster Pumping Systems



SUCTION AND DISCHARGE: Measure the hydraulic suction and discharge information.

	Diameter (m)	Material	Pressure (kg/cm²)	Flow (l/s)	Velocity (m/s)
Suction	0.1	SS		4.70	0.2837
Dischrge	0.1	SS	1.3	4.70	1.1348

Diameter – the diameter of the pipe (m).
Material – the suction and discharge pipe material type, which will be used to obtain the corresponding friction coefficient.
Pressure – install pressure gauges, or if the system already has an installed gauge, fill in the suction and discharge pressure readings (kg/cm^2); if there is no pressure gauge installed on the suction pipe and pressure cannot be measured at this point, leave this box blank.
Flow – the flow in the discharge pipe (l/s); the value will be the same for the suction pipe.
Velocity – speed of fluid measured in the discharge pipe (m/s). If the flow meter has this capability, input the speed information of the meter; if not, the spreadsheet has a formula to calculate this measurement.

TOPOGRAPHY: Measure the site elevations of water supply, the pumping system, and the point of water delivery to calculate the unevenness in terrain (m), which the pump must overcome in order to deliver the fluid.

TOPOGRAPHY:	**Elevation of the pump site:**	1,045 masl	**(meters above sea level)**
	Elevation of the highest delivery point:	1,047 masl	

Pump site elevation – the elevation where the pumping equipment is located, expressed in meters above sea level (masl).
Highest point of water delivery – the elevation of the highest water discharge point, as follows:

- **Delivery to a high-level tank –** the top of water in the tank.
- **Delivery direct to the water grid –** the point should be the highest elevation within the water distribution grid.

OBSERVATIONS: Describe any particular conditions or hydraulic system characteristics.

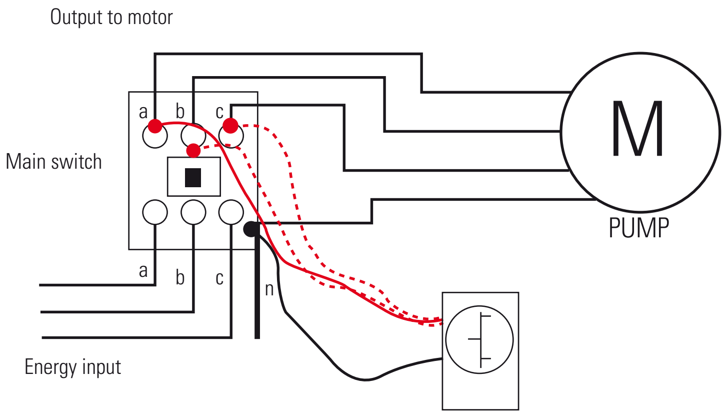
OBSERVATIONS:	The well is deviated, so the pump must be submersible.

2.2 ELECTRICAL MEASUREMENTS

Measure the electrical parameters, which are central to the balance analysis and energy audit.

VOLTAGE IN PHASES: Measure the voltage supply to the motor in each of the phases to ground or to neutral by taking readings with a voltmeter in the main switch or contactor that feeds directly to the motor input cables (see reference figure).

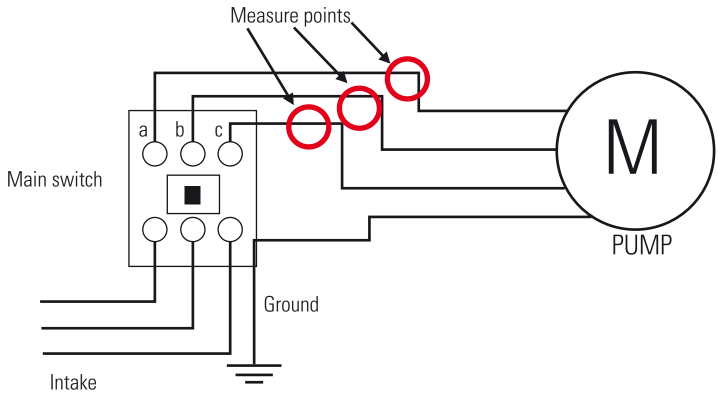
VOLTAGE BTWN STAGES: **Vab:** 260.4 **Vbc:** 261.9 **Vac:** 255.8



Van – voltage from phase "a" to neutral or ground (V).
Vbn – voltage from phase "b" to neutral or ground (V).
Vcn – voltage from phase "c" to neutral or ground (V).
Note: If you use a power analyzer that gives the reading between phases (ab, ac, cb), divide by a factor of 1.732.

CURRENT PHASE: Measure the electrical current in each phase conductor of the motor by using an amperometer with drop rings on each of the conductors (see figure).

CURRENT PHASE: **Ia:** 13.92 **Ib:** 14.14 **Ic:** 12.93



Ia – electric current in phase "a" (A).
Ib – electric current in phase "b" (A).
Ic – electric current in phase "c" (A).

ACTIVE POWER: Measure the active power (real electric power) to the motor in watts (W) with a watt-meter from each phase to ground.

ACTIVE POWER:	**Pa:**	2.92	**Pb:**	2.86	**Pc:**	2.61

Pa – active power in phase "a" (W).
Pb – active power in phase "b" (W).
Pc – active power in phase "c" (W).

POWER FACTOR: Measure the power factor in each phase.

Power Factor:	**PFa:**	0.806	**PFb:**	0.774	**PFc:**	0.791

PFa – power factor in phase "a".
PFb – power factor in phase "b".
PFc – power factor in phase "c".

HARMONIC DISTORTION: Measure this parameter only if harmonic analyzer equipment is available. If not, this data is not required.

HARMONIA DISTORTION:	**THD-V**	2.3	**THD-I**	3.1

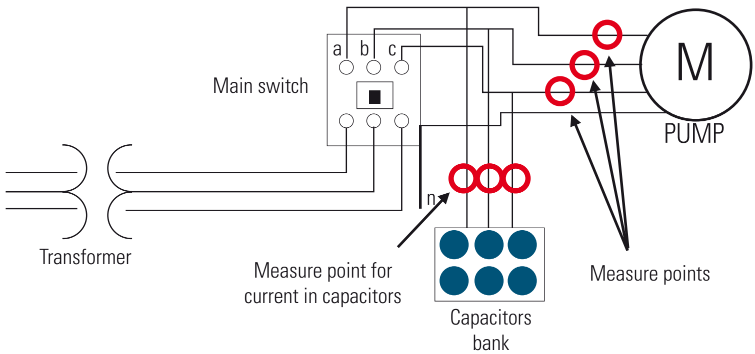
THD-V – factor of distortion measured in reference to the changes of the voltage swing.
THD-I – factor of distortion measured in reference to the changes of electric current swing.

MEASUREMENT POINT: Note the reference point where electrical measurements were completed; if the equipment has a capacitor bank, record whether the measurements were made before or after it.

Measurement point:	Main circuit

CAPACITOR CHECK: If a capacitor bank is used at the facilities, measure the current in each phase according to the figure below.

CAPACITOR CURRENT	**Ia:**	28	**Ib:**	31	**Ic:**	29



Ia – electric current in phase "a" in the capacitor bank (A).
Ib – electric current in phase "b" in the capacitor bank (A).
Ic – electric current in phase "c" in the capacitor bank (A).

GROUND SYSTEM: Evaluate the ground system using a ground resistance meter.

GROUND SYSTEM:	**Continuity:**	YES	NO	**Current:**	A	**Resistance:**	Ω

Continuity – check by ensuring that the grounding cable is not broken at any point; circle the appropriate box.
Current – electrical current reading in the ground resistance meter (A).
Resistance – resistance reading in the ground resistance meter (Ω).

OBSERVATIONS: Note any incidents that took place during the measurement process and the reasons for any missing information.

OBSERVATIONS:	Did not find continuity in the grounding wire, so no measurements were made of current and resistance.

2.3 TEMPERATURE MEASUREMENTS

Measure the temperatures of the equipment; this will provide additional information on the system's conditions and help determine the need for maintenance in the electrical system.

CONTROL EQUIPMENT: Measure the temperatures of the control equipment to test for a possible overload in the conductors, and to make sure all screws and conductor terminal fasteners are properly adjusted.

Control Equipment	Switch Input			Output Switch			Starter Input			Starter Output		
	A	B	C	A	B	C	A	B	C	A	B	C
	40	41	39	53	49	40	46	44	52	43	42	54

Switch input – provide temperature of the conductors coming from the transformer to the main switch in each of the stages (A, B, and C).
Output switch – temperature of the main switch towards the motor output in each of its phases (A, B, and C).
Starter input – temperature in the starter's entry in each of its phase conductors (A, B, and C).
Starter output – temperature of conductors to output terminals along the motor's starter in each of its phases (A, B, and C).

MOTOR: Measure the motor temperature to determine the need for maintenance in the motor and to make sure the shaft is balanced.

Motor		
Housing	Bearings	
	Upper	Lower
42	48	40

Housing – temperature of the housing (°C).
Bearings – temperatures of the bearings at the beginning (upper) and the end (lower) of the shaft.

TRANSFORMER: As with the control equipment, measure the temperatures of the transformer to test for a possible overload in the conductors, and to make sure all conductor terminal fasteners are properly adjusted.

Transformer										
Feeder Terminals			Low-voltage Terminals				Frame		Radiator	
X1	X2	X3	X0	X1	X2	X3	Upper	Lower	Upper	Lower
38	39	39	36	40	38	39	41	40	41	39

Feeder terminals – temperature of the electric feeder terminals that connect to the high-voltage side of the transformer in each of the phases (X_1, X_2, and X_3).
Low-voltage terminals – temperatures of the transformer on the low-voltage side, both in the neutral terminal output (X_0), as in each of the phases (X_1, X_2, and X_3).
Frame – temperature of the transformer on the top and the bottom of the frame (determines the operating temperature of the transformer and tests for overload).
Radiator – temperature of the transformer's radiator; measurements must be made both at the top and bottom of the radiator (determines indirectly the transformer oil temperature differential).

OBSERVATIONS: Note any occurrences while taking the required temperature measurements.

STEP 3. PROCESSING INFORMATION AND EVALUATION

Based on an assessment of the data obtained in the previous step, in step 3 it is necessary to determine the amount of lost energy and the efficiency of the various components of the pumping system.

3.1 ELECTRICAL CONDUCTORS EVALUATION

Calculate the losses in the electric conductors caused by the joule effect using the methodology spreadsheet. These losses are a function of the conductor's resistance and the square of the electric current.

Electrical Line (indicate the beginning and the end of the line being evaluated)		Caliber	Length	Resistance		Current	Oper.	Losses	
			m	Ω/km	Ω	A	h/year	kW	kWh/year
Actual condition	Transf.-Arrancador	40 AVG	18	0.1640	0.002952	39,3	8736	0.014	120
	Arrancador-Motor	40 AVG	152.5	0.1640	0.02501	39,3	8736	0.116	1.014

NECESSARY DATA:

CALIBER – the caliber of the electric conductors in American Wire Gauge (AWG), as measured according to Step 1.1 of this manual.
RESISTANCE – the resistance of the conductor (Ω/km) depends on the caliber and material of each conductor; this value can be obtained from the manufacturer table (see the table below for some common copper conductor sizes and their resistance values).

Caliber AWG	Resistance Ω/km
1/0	0.3290
2/0	0.2610
3/0	0.2070
4/0	0.1640
250	0.1390
300	0.1157
350	0.0991
400	0.0867
500	0.0695
600	0.0578

VALUES CALCULATED BY THE SPREADSHEET

Once the data is entered, the spreadsheet automatically determines the values for each section.

LENGTH – the length of the electric conductors (m) is determined using the data from Step 1.1.
RESISTANCE – the total resistance of the conductor (Ω) is obtained by multiplying the resistance per kilometer by the length of the conductors.
CURRENT – the average current measured in the three stages (A) is calculated according to the data collected in Step 2.2.
OPERATION TIME – operation time is determined using the data from Step 1.2 (h/year).
LOSSES – estimated losses generated by electric conductors (kWh/year); resistance multiplied by the square of the current $P=R*I^2$, and then multiplied by the annual operation time.

3.2 MOTOR EVALUATION

It is important to evaluate the efficiency of the electric motor in this methodology because this level represents the useful mechanical power output of total electric power consumed. The efficiency level is usually expressed as a percent of mechanical power over electrical power and can be calculated in several ways.

Based on the load factor (LF), first determine the parameters of imbalance of electrical parameters, especially the voltage, and then calculate the motor efficiency losses due to age, rewindings, or maintenance. In this case the spreadsheet automatically performs the calculations and transfers data into the corresponding boxes.

	Average	Unbalance	Status	V/vn
VOLTAGE (V)	445.37	0.8%	minimum	1.2%
CURRENT (A)	13.66	5.4%	average	
POWER (kW)	8.23	6.7%	high	
PF-Power Factor	78.1%	2.1%	low	

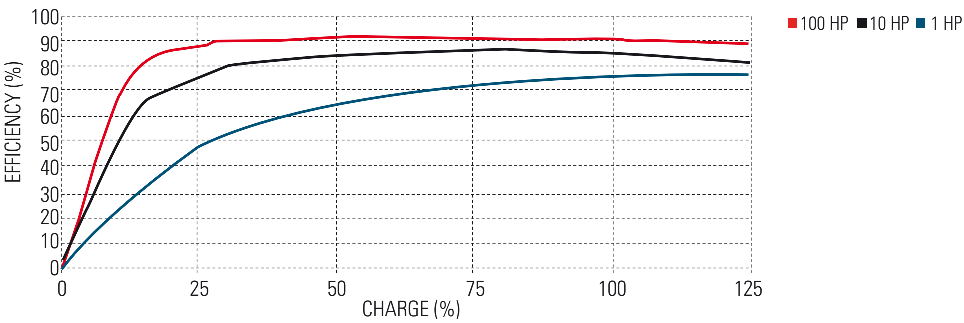
EFFICIENCY EVALUATION	
LF-Load Factor:	86.0%
η nominal	78.0%
Decrease	0.03%
η real	77.9%

MOTOR EFFICIENCY EVALUATION									
HP	**Effic.**	**LF**	**Effic. nom**	**Effic. 75%**	**Effic. 100%**	**FA ant**	**FA rew**	**FA w**	**FA dv**
10	77.9%	86.0%	78.0%	76.9%	79.3%	0.0%	0.0%	–0.000244	100.0%

NECESSARY DATA: MOTOR EFFICIENCY EVALUATION BOX

Efficiency 75 and 100 percent load: Enter this data according to the nominal curve of motor efficiency, in accordance with the manufacturer. The figure below shows typical efficiency curves for 1, 10, and 100 horsepower (HP) motors.

FIGURE 7 Typical Efficiency of Standard Squirrel-Cage Type Induction Motors of 1800 RPM



Effic.: Enter the nominal efficiency value from Step 1.2 into the motor efficiency evaluation chart. The spreadsheet will produce the corresponding values and calculate the real motor efficiency **(η real)** in the efficiency evaluation block. Enter this result under the **Effic.** field and a new value will be calculated. The value of the real motor efficiency **(η real)** must be placed in the motor efficiency evaluation box until there is no significant difference between the values in both boxes (see figure).

Efficiency Evaluation	
LF	86.0%
η nominal	78.0%
Decrease	0.03%
η real	77.9%

HP	Effic.	FC
10	77.9%	86.0%

VALUES CALCULATED BY THE SPREADSHEET:

Once these results are entered, the spreadsheet will calculate the corresponding values in the following boxes:

	Average	Imbalance	Status	V/Vn
VOLTAGE (V)	445.37	0.8%	minimum	1.2%
CURRENT (A)	13.66	5.4%	average	
POWER (kW)	8.23	6.7%	high	
PF	78.1%	2.1%	low	

VOLTAGE – the average voltage (V) measured in Step 2.2; the imbalance of tension between the calculated average and the voltage measured at each phase; the level of imbalance according to data calculated between phases; and the average voltage measured against the nominal voltage of the motor plate obtained in Step 1.2.
CURRENT – the average current (A) measured in Step 2.2; the average current imbalance of each phase; and the level of imbalance according to data calculated between phases.
POWER – the average active power in kilowatts (kW) measured in Step 2.2; the average active power imbalance of each phase; and the level of the imbalances calculated between phases.
PF – the average power factor calculated in Step 2.2; the average imbalance of power factors of each phase; and the level of imbalances calculated between phases.

MOTOR EFFICIENCY EVALUATION BOX

Motor Efficiency Evaluation									
HP	Effic.	LF	Nom. effic.	Effic. 75%	Effic. 100%	FA ant	FA rew	FA vv	FA dv
10	77.9%	86.0%	78.0%	76.9%	79.3%	0.0%	0.0%	–0,000244	100.0%

Horsepower – the nominal mechanical power of the motor in horsepower (HP), obtained from the motor plate values in Step 1.2.
LF – the load factor of the motor, obtained with the following formula: LF = Pe / Effic. x Horse Power x 0.746 (Pe = electrical power calculated as the sum of the three active powers, Pa, Pb, Pc [step 2.2], minus losses in the starter-motor unit [Step 3.1]).
Nom. effic. – nominal motor efficiency calculated through an interpolation between efficiencies entered at 75 and 100 percent of the motor nominal curve.
FA ant – loss factor of nominal efficiency according to the age of the motor, calculated automatically based on data in Step 1.2.
FA rew – efficiency loss factor of nominal efficiency according to the number of rewindings in the motor maintenance, based on data obtained in Step 1.2.
FA vv – motor efficiency loss factor, which depends on the imbalance or relationship of supplied voltage and nominal voltage, according to the electrical calculations box in volts over nominal voltage (V/Vn).
FA dv – motor efficiency loss factor (in the example it is related to the imbalance of voltage between phases according to the electrical calculations box).

EFFICIENCY EVALUATION BOX

This single box displays a summary of the calculated data in the motor efficiency evaluation box.

Efficiency Evaluation	
LF	86.0%
η nominal	78.0%
Decrease	0.03%
η real	77.9%

LF – load factor, calculated and taken from the appropriate box.
η nominal – nominal motor efficiency, calculated in Step 1.2 and placed in the corresponding box.
Decrease – voltage, age, and rewiring efficiency loss factors, calculated in Step 3.1.
η real – real efficiency of the motor; obtained by subtracting the nominal efficiency from the corresponding efficiency losses.

3.3 PUMP EVALUATION

The total efficiency of the operating pump is calculated as the ratio between the hydraulic power output (Ph) and the mechanical power absorbed (Pm). To calculate this efficiency, obtain the NET pumping load, accounting for loss of suction, discharge pipes, and gauge (manometer) power.

PUMPING LOAD

Suction line losses:	0.13 m	**Discharge line losses:**	0.001 m
Specific gravity of fluid:	1000 kg/m^3	**Discharge line speed:**	0.598 m/s
Net pumping load:	46.92 mwc	**Deviation from design:**	113.3%

FLOW

Flow measured:	0.0047 m^3/s	**Deviation from the design:**	–74.7%

MANOMETER POWER

Design:	4.02 kW	**Measurements:**	2.163 kW	**Deviation:**	–46.14%

EFFICIENCY

Electromecanical efficiency:	26.28%	**Pump efficiency:**	33.72%

Pipe Losses								
	Q	A	v	Visco	Reynolds	Rug. abs.	Rug. rel.	fr	Hfr
	m^3/s	m^2	m/s	m^2/s		mm			m.c.a.
Suction	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.00046	0.0218	0.129
Discharge	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.00046	0.0218	0.001

The spreadsheet automatically calculates the majority of the data needed based on the measurement of hydraulic and electrical parameters obtained in the Steps 2.1 and 2.2. However, it is essential to calculate the losses in suction and discharge pipes to obtain the net pumping load. In this step, the following new data is required:

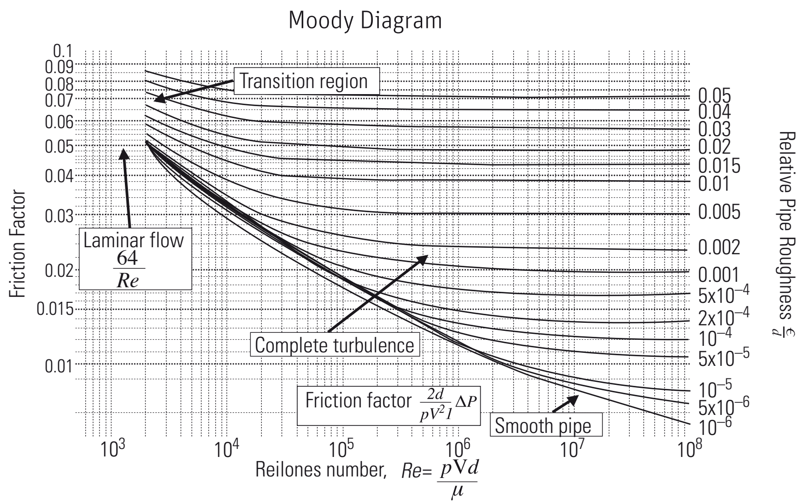
Pipe Losses									
	Q	A	v	Visco	Reynolds	Rug. abs.	Rug. rel.	fr	Hfr
	m^3/s	m^2	m/s	m^2/s		mm			m.c.a.
Suction	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.00046	0.0218	0.129
Discharge	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.00046	0.0218	0.001

Rug. abs. – absolute roughness of the pipeline (mm), which depends on material properties. This value is obtained using the table below and the Moody Diagram:

Material	Values of e for Different Pipe Types ε (mm)
Steel	0.9–9
Concrete	0.3–3
Cast iron	0.25
Galvanized iron	0.15
Forged asphalt iron	0.12
Forged iron	0.046
(PVC)	0.0015

fr – the friction factor can be obtained from the Moody Diagram by entering the Reynolds number (calculated by the spreadsheet in this box); the **fr** value must be entered in the corresponding box.

Material	ε (mm)
Concrete, coarse	0.25
Concrete, smooth	0.025
Drawn tubing	0.0025
Glass, plastic, Perspex	0.0025
Iron, cast	0.015
Sewers, old	3.0
Steel, mortar lined	0.1
Steel, rusted	0.5
Steel, structural or forged	0.025
Water mains, old	1.0



VALUES CALCULATED BY THE SPREADSHEET:

Once these data are entered, the spreadsheet will calculate the corresponding values:

Pipe Losses									
	Q	**A**	**v**	**Visco**	**Reynolds**	**Rug. abs.**	**Rug. rel.**	**fr**	**Hfr**
	m^3/s	**m^2**	**m/s**	**m^2/s**		**mm**			**m.c.a.**
Suction	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.000460	0.0218	0.129
Discharge	0.005	0.0079	0.5984	9.8E–07	6.096E+04	0.046	0.000460	0.0218	0.001

Q – pump flow (m^3/s), taken from Step 2.
A – area of the corresponding pipeline (m^2), calculated according to the pipe diameter (m) measured in Step 2.
V – fluid velocity (m/s).
Visco – kinematic viscosity (m^2/s), calculated based on the characteristics of the fluid temperature and specific weight obtained in Step 1.4.
Reynolds – the Reynolds number, obtained by multiplying the velocity of the fluid by pipe diameter, and then dividing by the fluid kinematic viscosity.
Rug. rel. – the relative roughness of the pipeline, obtained by dividing the absolute roughness by the diameter of the pipe.
Hfr – total load losses due to friction of the fluid with the walls of the corresponding pipes, obtained with the following formula:

$$Hfr = fr \frac{Pipe\ length}{diameter} \times \frac{v^2}{2g}$$

PUMP EFFICIENCY CALCULATION BOX

PUMPING LOAD

Suction line losses:	0.13 m	**Discharge line losses:**	0.001 m
Specific gravity of fluid:	1000 kg/m^3	**Discharge line speed:**	0.598 m/s
Net pumping load:	46.92 mwc	**Deviation from design:**	113.3%

FLOW

Flow measured:	0.0047 m^3/s	**Deviation from the design:**	–74.7%

MANOMETER POWER

Design:	4.02 kW	**Measurements:**	2.163 kW	**Deviation:**	–46.14%

EFFICIENCY

Electromecanical efficiency:	26.28%	**Pump efficiency:**	33.72%

Enter the suction and discharge piping losses. Values are then calculated automatically as follows:

PUMPING LOAD – determines the net pumping load, taking into account the hydraulic measurements in Step 2.1 and the losses in suction and discharge lines. It also determines the deviation of this from the nominal design load obtained in Step 1.3.

FLOW – determines the flow (m^3/s) and its deviation from the design or nominal flow obtained in Step 1.3.
MANOMETER POWER – calculates the gauge power, real work, and their deviation (kW), depending on the load and corresponding wear.
EFFICIENCY – determines the efficiency of the pump according to the following:

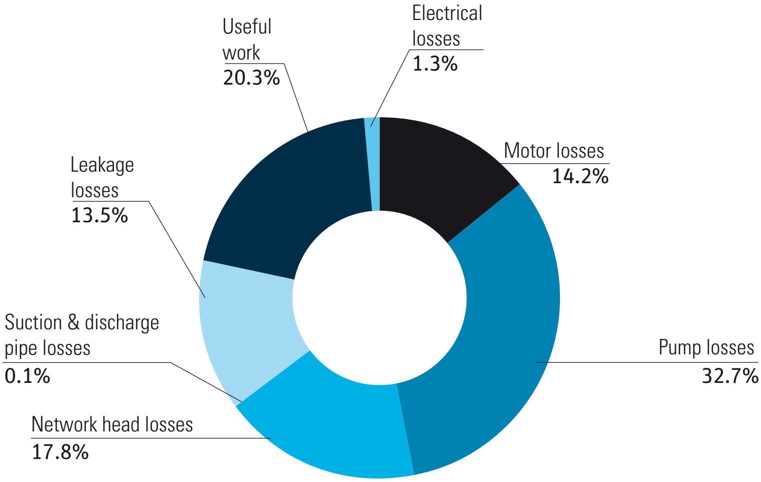
> **Electromechanical efficiency –** calculated by dividing the gauge power by the electrical power, as determined in Step 3.2.
> **Pump efficiency –** calculated by dividing the electromechanical efficiency by the real motor efficiency, as determined in Step 3.2.

3.4 ACTUAL ENERGY BALANCE

Calculate the energy balance to identify facilities or elements of the pumping system where the largest consumption of energy is located, and to plan savings measures accordingly. Determining the useful work will show the portion of energy used to do the actual work. The rest of consumed energy is lost in various elements of the pumping system. Use the spreadsheet to calculate this balance based on the measurements obtained in steps 2.1, 2.2, 3.1, and 3.3. Energy consumption can then be broken down.

Parameter	Unit	Amount
Energy consumption	kWh/year	73,651
Motor efficiency	%	77.93%
Pump efficiency	%	33.64%
Leakage losses	%	40%
Useful head	wcm	35
Electrical losses	kWh/year	1,538
Motor losses	kWh/year	15,917
Pump losses	kWh/year	37,292
Suction & discharge pipe losses	kWh/year	5
Network head losses	kWh/year	4,606
Leakage losses	kWh/year	5,717
Useful work	kWh/year	8,576

Actual Energy Balance



To determine the energy balance, enter the leakage loss percentage, obtained from the water distribution balance estimate for the hydraulic network. Energy balance depends on the conditions of the distribution network, and typical losses can range from 20 to 65 percent. Then calculate the power balance using the following data:

Energy consumption – the total energy consumed by the electrical system (kWh) in one year of operation, calculated as the sum of the average active power at all stages.
Motor efficiency – the real motor efficiency percentage, calculated in Step 3.2.
Pump efficiency – yhe pump efficiency percentage, calculated in Step 3.3.
Leakage losses – estimated water lost through leaks in the distribution network, according to previous studies of the network (a value must be entered in the cell).
Useful head – the pump load due to the physical and topographic elevations; the vertical distance between the suction and highest point of delivery, expressed in water column meters (wcm).
Electrical losses – energy losses due to electrical items; in this case, it is due to the conductor's energy losses as calculated in Step 3.1.
Motor losses – energy losses in the motor, according to the real motor efficiency calculated in Step 3.2.
Pump losses – energy losses due to the pump inefficiency, according to calculation in Step 3.3.
Suction & discharge pipe losses – energy losses caused by friction of the fluid in piping suction and discharge, calculated in Step 3.3.
Network head losses – total pumping load losses calculated by the difference between the net pumping load and the corresponding pressure gap.
Leakage losses – estimated energy losses from the fluid leaks in the distribution network, calculated based on the leakage factor lost.
Useful work – the real work expressed in units of energy actually needed by the pumping system (i.e., energy that is actually used by the pumping system to deliver the fluid).

3.5 COMMENTS AND SAVINGS OPPORTUNITIES

This section provides concluding comments of the energy balance and an analysis of measurements.

Some examples of comments and general savings opportunities include the following:

a) There are several anomalies in the ground system. Recommended a full assessment of standards compliant.
b) The power factor is low (78%). Recommend installing capacitor banks to reduce losses in electrical conductors by joule effect.
c) The temperature at the input and output terminals of the main switch and starter are high (above 40º C). Consider performing predictive and preventive maintenance to maintain the good operation of equipment.
d) The imbalance in the calculated power is high, which is an indication that the motor is working poorly.
e) The pump efficiency is very low (33.36%). Recommend replacement.

Analysis of the Motor Evaluation and Electric Parameters

a) Power factors can cause increased joule losses in
- conductors between the power supply and the motor;
- wiring of the transformer; and
- operation and protection devices.

b) Increased voltage drop in the feeders results in low input voltage on motors, thus causing efficiency losses.

c) Increased apparent power reduces the ability of the installed load, which is important in the case of distribution transformers.

These conditions affect the producer and distributor of electrical energy, which then penalize the users for their electricity consumption with higher fees. One of the causes of a low power factor is a motor working with a low load factor (usually because it is oversized).

The following table presents a more extensive list of inefficient operating conditions that are often present in electric motors, as well as the diagnosis of the cause.

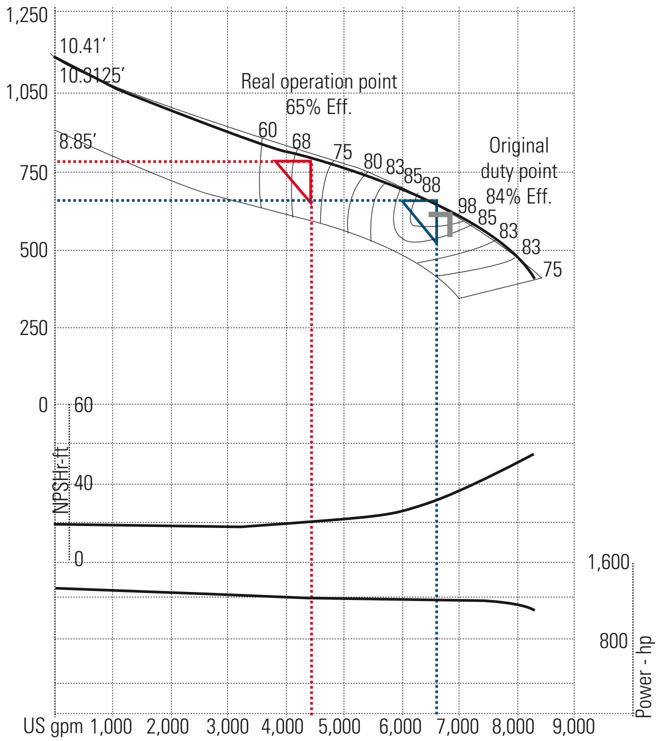
Observed condition	Diagnosis
Lower voltage than the nominal.	The incoming voltage from the outside service is deficient.
	The intake voltage presents variability up to 5 percent.
	The intake voltage is ok.
Imbalance of voltage power supply to the motor.	The intake voltage is imbalanced.
	The intake voltage is ok, but the outer voltage is imbalanced.
	The voltage at the terminals of the transformer is balanced, and motor power is imbalanced.
Imbalance in the currents used by the motor.	The imbalance in power is inversely proportional to the imbalance in voltage.
	The imbalance is produced by a demand imbalance by the motor phases.
The motor operational speed is under full load speed.	Problems with bearings.
High temperature and/or high vibration in bearings.	
The motor is standard efficiency and has more than 10 years of operation.	Motor operation efficiency is low.
The motor has been repaired (rewound) more than twice.	Motor efficiency is depreciated.
The motor is currently working with a load factor less than 45 percent.	The motor is currently working in an area where its efficiency of operation is low.
The motor is currently working with a load factor greater than 100 percent.	The motor is currently working in an area where its efficiency of operation is low.

Pump Evaluation Analysis

Analyzing pumps working in parallel is important for diagnosing excessive energy consumption. Correcting such conditions will result in substantial power savings. Actual electromechanical efficiency and pump efficiency must be compared with the values recommended in applicable motor standards. Such comparisons can be used to determine potential energy savings levels. This analysis will serve as a basis for considering the replacement of equipment during the subsequent review of the project portfolio. Some recommended standards for minimum values of electromechanical efficiency are as follows:

Power Intervals		Electromechanical Efficiency (%)
kW	HP	
5.6–14.9	7.5–20	52
15.7–37.3	21–50	56
38.0–93.3	51–125	60
94.0–261	126–350	64

On the other hand, it is very common to find pumping systems operating in less than optimal conditions. According to design, all pumps have an optimal operating load point, in which all losses are minimized. Some problems that may arise include low productivity; degradation of pump parts, particularly of impellers and wear rings; and cavitations caused by low flow in the suction. The effects of reducing the efficiency of the pumping system are shown in the figure below. It is significant in terms of transaction of load flow, and can vary up to 20 percent in terms of efficiency.



The result is a percentage of deviation between the green and red lines. If the percentage deviation is negative, the pump is operating at the left of the green line. If the percentage deviation is positive, the pump is operating at the right of the green line.

Obtained Temperatures Analysis

The measurements taken in Step 1.4 will help reveal a lack of maintenance in the electrical installations, either in the connections of the conductor terminals or in the electrical equipment. The analysis of this data will help develop energy saving solutions.

STEP 4. ENERGY SAVING PROJECT

The purpose of the energy saving project is to develop a portfolio of possible opportunities to reduce energy costs. The project is based on the analysis of the information obtained during Step 3, including the analysis of efficiencies, operation, maintenance, and other areas of opportunity.

4.1 ENERGY SAVING PROPOSAL DESCRIPTION

The corresponding box on the spreadsheet describes energy saving proposals (see example).

4.1 Energy Saving Proposal Description
1. Replace the pump and motor sumersible assembly for more efficient equipment. The proposed equipment is submersible by the deviation of the well.
2. Install a capacitor bank.

The table below summarizes general and specific measures based on low, medium, and high investments that are commonly used to ensure optimal operating conditions and reduce energy consumption.

<table>
<tr><th>System</th><th>General Measure</th><th colspan="2">Specific Measure</th></tr>
<tr><td rowspan="6">Motor-pump system</td><td rowspan="4">Electromechanical efficiency optimization</td><td rowspan="2">Low investment</td><td>Make sure adequacy of pumping equipment meets actual operating points</td></tr>
<tr><td>Adjust the position of the conductors in turbine with open impeller pumps</td></tr>
<tr><td rowspan="2">Medium investment</td><td>Motor replacement</td></tr>
<tr><td>Motor – pump replacement</td></tr>
<tr><td rowspan="2">Preventive and predictive maintenance</td><td rowspan="2">Low investment</td><td>Monitor parameters related to electromechanical efficiency</td></tr>
<tr><td>Monitor mechanical parameters such as vibration and temperatures</td></tr>
<tr><td rowspan="4">Water distribution system</td><td rowspan="2">Optimize pumping loads</td><td>Low investment</td><td>Correct defects in the discharge piping configuration and operation</td></tr>
<tr><td>High investment</td><td>Reduce losses caused by friction in pipes</td></tr>
<tr><td rowspan="2">Pressure and flow control</td><td>Medium investment</td><td>Install variable frequency drive pumps</td></tr>
<tr><td>High investment</td><td>Regulate tanks installation</td></tr>
<tr><td rowspan="5">Electrical system</td><td rowspan="5">Optimization of electrical installations</td><td rowspan="3">Low investment</td><td>Power factor optimization</td></tr>
<tr><td>Correct voltage imbalances</td></tr>
<tr><td>Adjust motor voltage supply to the nameplate value</td></tr>
<tr><td rowspan="2">Medium investment</td><td>Reduce power loss per Joule effect</td></tr>
<tr><td>Reduce losses in transformers</td></tr>
</table>

4.2 EQUIPMENT SPECIFICATION

If the energy saving measures described in Step 4.1 require the replacement or change of equipment, the specifications should be annotated in the corresponding box as follows:

Pump specification	**Make:**	Goulds
	Model:	5 RWAHC (3 STAGES)
	Pump efficiency:	73.5%
Motor specification	**Nominal power:**	5.0 HP
	Nominal voltage:	440 V
	Efficiency at full load:	76.8%
	Number of phases:	2
	Angular velocity:	3500 rpm
	Electromechanical efficiency:	54.6%
Capacitor bank	**Capacity:**	2 kVars
	Nominal voltage:	440 V

Pump specification – key features of proposed replacement pump, such as brand, model, and efficiency of the pump.
Motor specification – characteristics of the proposed motor, such as power (HP), nominal voltage, efficiency at full load, number of phases of work, and angular velocity; the spreadsheet automatically determines the new electromechanical efficiency of the proposed pumps and motors by multiplying their efficiencies.
Capacitor bank – capacity of the bank (kVar) and the corresponding voltage (V) (if applicable).

4.3 ACTION PLAN

This box describes the actions that should be prioritized and tracked according to energy savings methods proposed in Step 4.1.

Actions:
i. Replace submersible equipment pump.
ii. Reuse existing electric conductor and control equipment for above.
iii. Install valve check.
iv. Install capacitors bank.

STEP 5. EVALUATION OF ENERGY SAVINGS

Once the proposed efficiency measures, the equipment change specifications, and the energy savings and energy balance evaluations are made, create a a savings plan.

5.1 ELECTRICAL CONDUCTORS EVALUATION

Reevaluate losses in the electric conductors and the joule effect to reflect any changes proposed for this area.

Electrical Line (indicate the beginning and the end of the line being evaluated)		Caliber	Length	Resistance	Current	Oper.	Losses	
			m	Ω/km	Ω	A	kW	kWh/año
Current Status	Transformer-Starter	8 AWG	15	2.10	0.0315	5.4	0.003	24
	Starter-Motor	12 AWG	53	5.32	0.28196	6.6	0.036	318

This assessment is performed just as described in Step 3.1. Enter the caliber of the conductor and the resistance in ohms per kilometer (Ω/km) and the spreadsheet will calculate new losses in conductors in kilowatt hours per year (kWh/year).

5.2 MOTOR EFFICIENCY CALCULATION

Recalculate the real efficiency of any new motor.

PF	BHP	HP proposed	Real effic.	LF	Effic. nom.	Effic. 75%	Effic. 100%
78.3%	3.95%	5.0%	74.2%	78.9%	74.3%	73.8%	76.8%

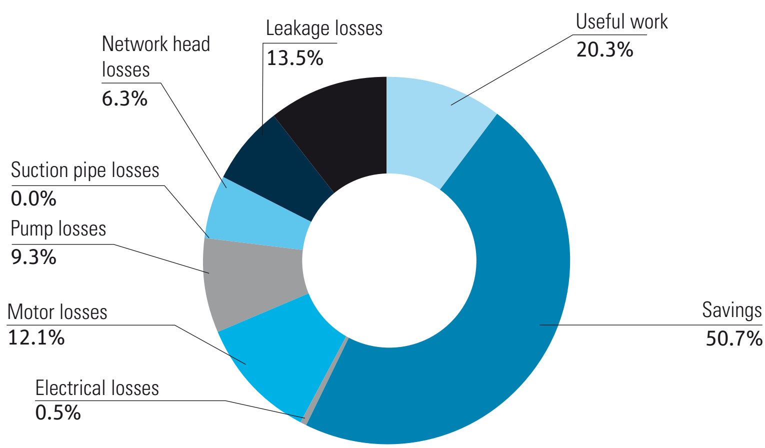
FA ant	FA rew	FA vv	FA dv
0.0%	0.0%	–0.00024	100.0%

This assessment is carried out similarly to the process described in Step 3.2, except that efficiencies must be 75 and 100 percent of the efficiency of the new motor curve. The spreadsheet will reflect these corresponding operations.

5.3 EXPECTED ENERGY BALANCE

When the proposed energy saving measures are implemented, the energy balance will reflect the load-flow curve of the new pump. Calculate the energy balance, as in Step 3.4, to determine the potential savings:

Parameter	Unit	Amount
Energy consumption	kWh/year	34,998
Power demand	kW	4.0
Current	A	6.6
Power factor	%	78%
Electrical losses	kWh/year	342
Motor losses	kWh/year	8,936
Pump losses	kWh/year	6,816
Suction pipe losses	kWh/year	5
Network head losses	kWh/year	4,606
Leakages losses	kWh/year	5,717
Useful work	kWh/year	8,576
Savings	kWh/year	38,653



In this case, expected energy consumption savings can reach up to 52.5 percent.

STEP 6. ECONOMIC ANALYSIS

The last step involves an economic analysis of proposed savings.

6.1 CALCULATION OF SAVINGS

Calculate the savings based on the cost of electrical energy and the energy savings obtained in Step 5.

Cost of energy		0.12	US$kWh
Direct savings:	The direct benefits come from the reduction of losses in the pump and motor		
	Energy saved	38,576	kWh/year
	Electricity savings invoice	4,629	USD/year
Additional savings:	The proposed motor will work with a better power factor and will demand a lower current, which results in a reduced joule effect on conductors.		
	Savings: energy conductors	1,194	kWh/year
	Savings: electricity invoice	143	USD/year

Energy cost – enter the overall cost of electricity in local currency units or in U.S. dollars per kilowatt hour (USD/kWh); this cost depends on local electricity rates or reflects a supply rate agreement between the pumping system and the service supplier.

Direct savings – expected savings from reducing energy losses as reflected in the new energy balance; these savings come from the line in the spreadsheet of the energy balance showing expected kWh/year savings, and the value is obtained by multiplying the energy saved by the cost of energy.

Additional savings – additional savings that may occur due to changes in the power factor. Although these savings are small, they should not be disregarded. However, if a low power factor results in additional fees from the supplier of electric power service, these must be included in the analysis.

Note: Insert the value of the cost of energy in the corresponding box and these savings will be calculated automatically.

6.2 INVESTMENT CALCULATION

Use the spreadsheet to calculate the total of investments made to purchase and install new equipment, if applicable.

Item	Description	Amount	Unit price (USD)	Total cost (USD)
1	Submersible pump motor assembly	1	3,431	3,431
2	Remove current pumping equipment and install proposed	1	1,000	1,000
3	Capacitors bank 5 kVar, 480 Volts. Supply and installation	1	245	245
			TOTAL	5,377

6.3 PROFITABILITY ANALYSIS

Use the spreadsheet to calculate the return on investment of the proposed energy saving projects.

Total savings:	Reduction in energy consumption	38,576
	Savings (US$/year)	**4,629**
Total investment:	**US$**	**5,377**
Pay-back period:	**years:**	**1.2**

Total savings – savings in energy cost calculated in section 6.1.
Total investment – cost of the purchase and installation of equipment as described in section 6.2.
Pay-back period – years it will take for the savings to cover the cost of the purchase and installation of equipment (calculated by dividing total investment by total savings).

WITH THIS CALCULATION, THE ENERGY SAVING AUDIT IS COMPLETE

www.iadb.org