PUMP LIFE CYCLE COSTS:

A GUIDE TO LCC ANALYSIS FOR PUMPING SYSTEMS

EXECUTIVE SUMMARY

Office of Industrial Technologies
Energy Efficiency and Renewable Energy
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Hydraulic Institute

Europump

Introduction

Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems is the result of a collaboration between the Hydraulic Institute, Europump, and the US Department of Energy's Office of Industrial Technologies (OIT).

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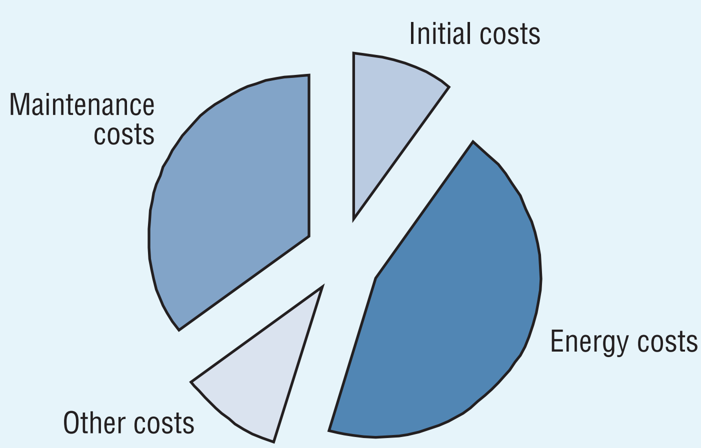
Improving Pump System Performance: An Overlooked Opportunity?

The life cycle cost (LCC) of any piece of equipment is the total "lifetime" cost to purchase, install, operate, maintain, and dispose of that equipment.

Pumping systems account for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations. Pumping systems are widespread; they provide domestic services, commercial and agricultural services, municipal water/wastewater services, and industrial services for food processing, chemical, petrochemical, pharmaceutical, and mechanical industries. Although pumps are typically purchased as individual components, they provide a service only when operating as part of a system. The energy and materials used by a system depend on the design of the pump, the design of the installation, and the way the system is operated. These factors are interdependent. What's more, they must be carefully matched to each other, and remain so throughout their working lives to ensure the lowest energy and maintenance costs, equipment life, and other benefits. The initial purchase price is a small part of the life cycle cost for high usage pumps. While operating requirements may sometimes override energy cost considerations, an optimum solution is still possible.

A greater understanding of all the components that make up the total cost of ownership will provide an opportunity to dramatically reduce energy, operational, and maintenance costs. Reducing energy consumption and waste also has important environmental benefits.

Life Cycle Cost (LCC) analysis is a management tool that can help companies minimize waste and maximize energy efficiency for many types of systems, including pumping systems. This overview provides highlights from *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems,* developed by the Hydraulic Institute and Europump to assist plant owners/operators in applying the LCC methodology to pumping systems. For information on obtaining a copy of the *Guide*, see page 15 of this summary.



Typical life cycle costs for a medium-sized industrial pump

Pumping systems acount for nearly 20% of the world's electrical energy demand and range from 25-50% of the energy usage in certain industrial plant operations

In some industrial plant operations, pumping systems account for 25 to 50% of energy use.

What is Life Cycle Cost?

The life cycle cost (LCC) of any piece of equipment is the total "lifetime" cost to purchase, install, operate, maintain, and dispose of that equipment. Determining LCC involves following a methodology to identify and quantify all of the components of the LCC equation.

When used as a comparison tool between possible design or overhaul alternatives, the LCC process will show the most cost-effective solution within the limits of the available data.

The components of a life cycle cost analysis typically include initial costs, installation and commissioning costs, energy costs, operation costs, maintenance and repair costs, down time costs, environmental costs, and decommissioning and disposal costs.

Why Should Organizations Care About Life Cycle Cost?

Many organizations only consider the initial purchase and installation cost of a system. It is in the fundamental interest of the plant designer or manager to evaluate the LCC of different solutions before installing major new equipment or carrying out a major overhaul. This evaluation will identify the most financially attractive alternative. As national and global markets continue to become more competitive, organizations must continually seek cost savings that will improve the profitability of their operations. Plant equipment operations are receiving particular attention as a source of cost savings, especially minimizing energy consumption and plant downtime.

Existing systems provide a greater opportunity for savings through the use of LCC methods than do new systems for two reasons. First, there are at least 20 times as many pump systems in the installed base as are built each year; and, second, many of the existing systems have pumps or controls that are not optimized since the pumping tasks change over time.

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In addition to the economic reasons for using LCC, many organizations are becoming increasingly aware of the environmental impact of their businesses, and are considering energy efficiency as one way to reduce emissions and preserve natural resources.

Getting Started

LCC analysis, either for new facilities or renovations, requires the evaluation of alternative systems. For a majority of facilities, the lifetime energy and/or maintenance costs will dominate the life cycle costs. It is therefore important to accurately determine the current cost of energy, the expected annual energy price escalation for the estimated life, along with the expected maintenance labor and material costs. Other elements, such as the life time costs of down time, decommissioning, and environmental protection, can often be estimated based on historical data for the facility. Depending upon the process, down time costs can be more significant than the energy or maintenance elements of the equation. Careful consideration should therefore be given to productivity losses due to down time.

This overview provides an introduction to the life cycle costing process. The complete *Guide* expands upon life cycle costing and provides substantial technical guidance on designing new pumping systems as well as assessing improvements to existing systems. The *Guide* also includes a sample chart, examples of manual calculation of LCC, and a software tool to assist in LCC calculation.

Life Cycle Cost Analysis

In applying the evaluation process, or in selecting pumps and other equipment, the best information concerning the output and operation of the plant must be established. The process itself is mathematically sound, but if incorrect or imprecise information is used then an incorrect or imprecise assessment will result. The LCC process is a way to predict the most cost-effective solution; it does not guarantee a particular result, but allows the plant designer or manager to make a reasonable comparison between alternate solutions within the limits of the available data.

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Pumping systems often have a lifespan of 15 to 20 years. Some cost elements will be incurred at the outset and others may be incurred at different times throughout the lives of the different solutions being evaluated. It is therefore practicable, and possibly essential, to calculate a *present or discounted* value of the LCC in order to accurately assess the different solutions.

This analysis is concerned with assessments where details of the system design are being reviewed. Here the comparison is between one pump type and another, or one control means and another. The exercise may be aimed at determining what scope could be justified for a monitoring or control scheme, or for different process control means to be provided. Whatever the specifics, the designs should be compared on a like-for-like basis. To make a fair comparison, the plant designer/manager might need to consider the measure used. For example, the same process output volume should be considered and, if the two items being examined cannot give the same output volume, it may be appropriate to express the figures in cost per unit of output (e.g., $/ton, or Euro/kg). The analysis should consider all significant differences between the solutions being evaluated.

Finally, the plant designer or manager might need to consider maintenance or servicing costs, particularly where these are to be subcontracted, or spare parts are to be provided with the initial supply of the equipment for emergency stand-by provision. Whatever is considered must be on a strictly comparable basis. If the plant designer or manager decides to subcontract or carry strategic spares based entirely on the grounds of convenience, this criterion must be used for all systems being assessed. But, if it is the result of maintenance that can be carried out only by a specialist subcontractor then its cost will correctly appear against the evaluation of that system.

Elements of the LCC equation

$$LCC = C_{ic} + C_{in} + C_e + C_o + C_m + C_s + C_{env} + C_d$$

- LCC = life cycle cost
- C_{ic} = initial costs, purchase price (pump, system, pipe, auxiliary services)
- C_{in} = installation and commissioning cost (including training)
- C_e = energy costs (predicted cost for system operation, including pump driver, controls, and any auxiliary services)
- C_o = operation costs (labor cost of normal system supervision)
- C_m = maintenance and repair costs (routine and predicted repairs)
- C_s = down time costs (loss of production)
- C_{env} = environmental costs (contamination from pumped liquid and auxiliary equipment)
- C_d = decommissioning/disposal costs (including restoration of the local environment and disposal of auxiliary services).

The following sections examine each element and offer suggestions on how a realistic value can be determined for use in computing the LCC. It should be noted that this calculation does not include the raw materials consumed by the plant in making a product.

C_{ic} - Initial Investment Costs

The pump plant designer or manager must decide the outline design of the pumping system. The smaller the pipe and fitting diameters, the lower the cost of acquiring and installing them. However, the smaller diameter installation requires a more powerful pump resulting in higher initial and operating costs. In addition, smaller pipe sizes on the inlet side of a pump will reduce the net positive suction head available (NPSHA), thus requiring a larger and slower speed pump, which will typically be more expensive. Provisions must be made for the acceleration head needed for positive displacement pumps or the depth of submergence needed for a wet pit pump.

There will be other choices, which may be made during the design stage that can affect initial investment costs. One important choice is the quality of the equipment being selected. There may be an option regarding materials having differing wear rates, heavier duty bearings or seals, or more extensive control packages, all increasing the working life of the pump. These and other choices may incur higher initial costs but reduce LCC costs.

The initial costs will also usually include the following items:

- engineering (e.g. design and drawings, regulatory issues)
- the bid process
- purchase order administration
- testing and inspection
- inventory of spare parts
- training
- auxiliary equipment for cooling and sealing water

C_{in} - Installation and Commissioning (Start-up) Costs

Installation and commissioning costs include the following:

- foundations—design, preparation, concrete and reinforcing, etc.
- setting and grouting of equipment on foundation
- connection of process piping
- connection of electrical wiring and instrumentation
- connection of auxiliary systems and other utilities
- provisions for flushing or ‘water runs’
- performance evaluation at start-up

Installation can be accomplished by an equipment supplier, contractor, or by user personnel. This decision depends on several factors, including the skills, tools, and equipment required to complete the installation; contractual procurement requirements; work rules governing the installation site; and the availability of competent installation personnel. Plant or contractor personnel should coordinate site supervision with the supplier. Care should be taken to follow installation instructions carefully. A complete installation includes transfer of equipment operation and maintenance requirements via training of personnel responsible for system operation.

Commissioning requires close attention to the equipment manufacturer’s instruction for initial start-up and operation. A checklist should be used to ensure that equipment and the system are operating within specified parameters. A final sign off typically occurs after successful operation is demonstrated.

C_e - Energy Costs

Energy consumption is often one of the larger cost elements and may dominate the LCC, especially if pumps are run more than 2000 hours per year

Energy consumption is often one of the larger cost elements and may dominate the LCC, especially if pumps run more than 2000 hours per year. Energy consumption is calculated by gathering data on the pattern of the system output. If output is steady, or essentially so, the calculation is simple. If output varies over time, then a time-based usage pattern needs to be established.

The input power calculation formula is:

$$P = \frac{Q \times H \times s.g.}{366 \times \eta_p \times \eta_m} \quad [kW] \quad (metric)$$

$$P = \frac{Q \times H \times s.g.}{3960 \times \eta_p \times \eta_m} \quad [hp] \quad (U.S.\ units)$$

where: P = power

Q = rate of flow, m^3/hr (US gpm)

H = head, m (ft.)

η_p = pump efficiency

η_m = motor efficiency

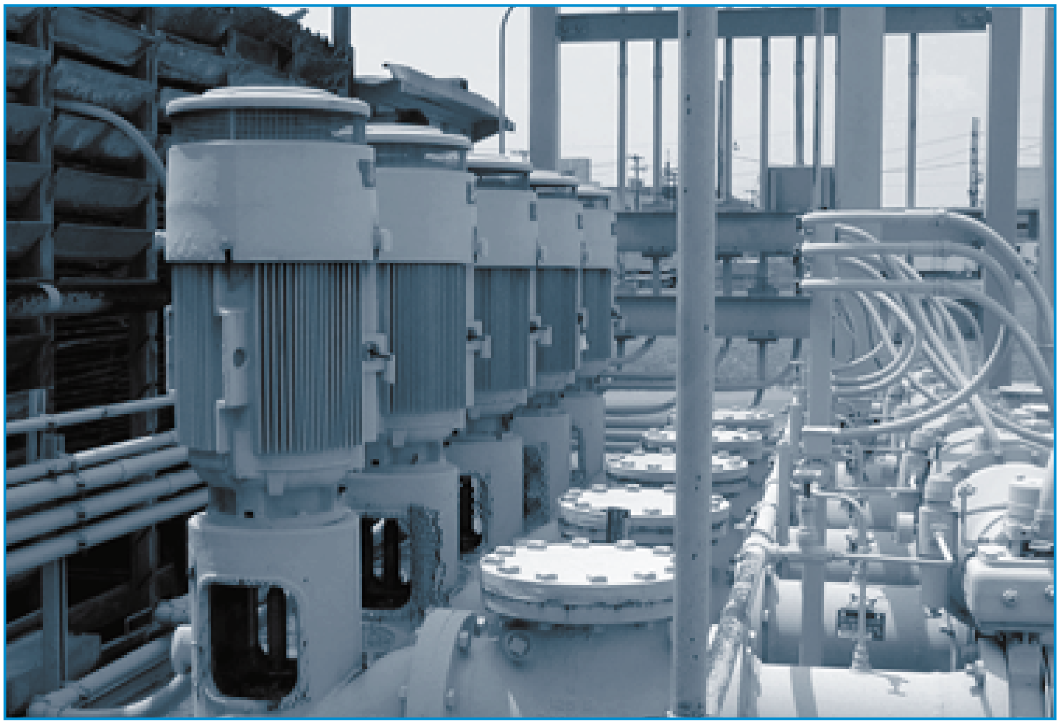
s.g. = specific gravity

The plant designer or manager needs to obtain separate data showing the performance of each pump/system being considered over the output range. Performance can be measured in terms of the overall efficiencies of the pump unit or of the energies used by the system at the different output levels. Driver selection and application will affect energy consumption. For example, much more electricity is required to drive a pump with an air motor than with an electric motor. In addition, some energy use may not be output dependent. For example, a control system sensing output changes may itself generate a constant energy load, whereas a variable speed electric motor drive may consume different levels of energy at different operating settings. The use of a throttling valve, pressure relief, or flow by-pass for control will reduce the operating efficiency and increase the energy consumed.

The efficiency or levels of energy used should be plotted on the same time base as the usage values to show their relationship to the usage pattern. The area under the curve then represents the total energy absorbed by the system being reviewed over the selected operating cycle. The result will be in kWh (kilowatt-hours). If there are differential power costs at different levels of load, then the areas must be totaled within these levels.

Once the charge rates are determined for the energy supplied, they can be applied to the total kWh for each charge band (rate period). The total cost of the energy absorbed can then be found for each system under review and brought to a common time period.

Finally, the energy and material consumption costs of auxiliary services need to be included. These costs may come from cooling or heating circuits, from liquid flush lines, or liquid/gas barrier arrangements. For example, the cost of running a cooling circuit using water will need to include the following items: cost of the water, booster pump service, filtration, circulation, and heat extraction/dissipation.



Maintenance and repair is a significant component of pumping system life cycle costs and an effective maintenance program can minimize these costs.

C_o - Operation Costs

Obtaining optimum working life from a pump requires regular and efficient servicing

Operation costs are labor costs related to the operation of a pumping system. These vary widely depending on the complexity and duty of the system. For example, a hazardous duty pump may require daily checks for hazardous emissions, operational reliability, and performance within accepted parameters. On the other hand, a fully automated non-hazardous system may require very limited supervision. Regular observation of how a pumping system is functioning can alert operators to potential losses in system performance. Performance indicators include changes in vibration, shock pulse signature, temperature, noise, power consumption, flow rates, and pressure.

C_m - Maintenence and Repair Costs

Obtaining optimum working life from a pump requires regular and efficient servicing. The manufacturer will advise the user about the frequency and the extent of this routine maintenance. Its cost depends on the time and frequency of service and the cost of materials. The design can influence these costs through the materials of construction, components chosen, and the ease of access to the parts to be serviced.

The cost of unexpected downtime and lost production is a very significant item in the total LCC and can rival the energy costs and replacement parts costs in its impact

The maintenance program can be comprised of less frequent but more major attention as well as the more frequent but simpler servicing. The major activities often require removing the pump to a workshop. During the time the unit is unavailable to the process plant, there can be loss of product or a cost from a temporary replacement. These costs can be minimized by programming major maintenance during annual shut-down or process change-over. Major service can be described as “pump unit not reparable on site,” while the routine work is described as “pump unit reparable on site.”

The total cost of routine maintenance is found by multiplying the costs per event by the number of events expected during the life cycle of the pump.

Although unexpected failures cannot be predicted precisely, they can be estimated statistically by calculating mean time between failures (MTBF). MTBF can be estimated for components and then combined to give a value for the complete machine.

It might be sufficient to simply consider best and worst case scenarios where the shortest likely life and the longest likely lifetimes are considered. In many cases, plant historical data is available.

The manufacturer can define and provide MTBF of the items whose failure will prevent the pump unit from operating or will reduce its life expectancy below the design target. These values can be derived from past experience or from theoretical analyses. The items can be expected to include seals, bearings, impeller/valve/port wear, coupling wear, motor features, and other special items that make up the complete system. The MTBF values can be compared with the design working life of the unit and the number of failure events calculated.

It must be recognized that process variations and user practices will almost certainly have a major impact upon the MTBF of a plant and the pumps incorporated in it. Whenever available, historical data is preferable to theoretical data from the equipment supplier. The cost of each event and the total costs of these unexpected failures can be estimated in the same way that routine maintenance costs are calculated.

C_s - Downtime and Loss of Production Costs

The cost of unexpected downtime and lost production is a very significant item in the total LCC and can rival the energy costs and replacement parts costs in its impact. Despite the design or target life of a pump and its components, there will be occasions when an unexpected failure occurs. In those cases where the cost of lost production is unacceptably high, a spare pump may be installed in parallel to reduce the risk. If a spare pump is used, the initial cost will be greater but the cost of unscheduled maintenance will include only the cost of the repair.

The cost of lost production is dependent on downtime and differs from case to case.

C_{env} - Environmental Costs, Including Disposal of Parts and Contamination from Pumped Liquid

The cost of contaminant disposal during the lifetime of the pumping system varies significantly depending on the nature of the pumped product. Certain choices can significantly reduce the amount of contamination, but usually at an increased investment cost. Examples of environmental contamination can include: cooling water and packing box leakage disposal; hazardous pumped product flare-off; used lubricant disposal; and contaminated used parts, such as seals. Costs for environmental inspection should also be included.

C_d - Decommissioning/Disposal Costs, Including Restoration of the Local Environment

In the vast majority of cases, the cost of disposing of a pumping system will vary little with different designs. This is certainly true for non-hazardous liquids and, in most cases, for hazardous liquids also. Toxic, radioactive, or other hazardous liquids will have legally imposed protection requirements, which will be largely the same for all system designs. A difference may occur when one system has the disposal arrangements as part of its operating arrangements (for example, a hygienic pump designed for cleaning in place) while another does not (for example, a hygienic pump designed for removal before cleaning). Similar arguments can be applied to the costs of restoring the local environment. When disposal is very expensive, the LCC becomes much more sensitive to the useful life of the equipment.

Total Life Cycle Costs

Proper pumping system design is the most important single element in minimizing the LCC

The costs estimated for the various elements making up the total life cycle costs need to be aggregated to allow a comparison of the designs being considered. This is best done by means of a tabulation which identifies each item and asks for a value to be inserted. Where no value is entered, an explanatory comment should be added. The estimated costs can then be totaled to give the LCC values for comparison, and attention will also be drawn to non-qualitative evaluation factors.

There are also financial factors to take into consideration in developing the LCC. These include:

- present energy prices
- expected annual energy price increase (inflation) during the pumping system life time
- discount rate
- interest rate
- expected equipment life (calculation period)

In addition, the user must decide which costs to include, such as maintenance, down time, environmental, disposal, and other important costs.

Pumping System Design

Proper pumping system design is the most important single element in minimizing the LCC. All pumping systems are comprised of a pump, a driver, pipe installation, and operating controls, and each of these elements is considered individually. Proper design considers the interaction between the pump and the rest of the system and the calculation of the operating duty point(s). The characteristics of the piping system must be calculated in order to determine required pump performance. This applies to both simple systems as well as to more complex (branched) systems.

By developing a model of the piping system, one can easily consider system alternatives, but the model must first be validated to insure that it accurately represents the operating piping system it is trying to emulate

Both procurement costs and operational costs make up the total cost of an installation during its lifetime. A number of installation and operational costs are directly dependent on the piping diameter and the components in the piping system.

A considerable amount of the pressure losses in the system are caused by valves, in particular control valves in throttle-regulated installations. In systems with several pumps, the pump workload is divided between the pumps, which together, and in conjunction with the piping system, deliver the required flow.

The piping diameter is selected based on the following factors:

- economy of the whole installation (pumps and system)
- required lowest flow velocity for the application (e.g., avoid sedimentation)
- required minimum internal diameter for the application (e.g., solids handling)

- maximum flow velocity to minimize erosion in piping and fittings
- plant standard pipe diameters

Decreasing the pipeline diameter has the following effects:

- Piping and component procurement and installation costs will decrease.
- Pump installation procurement costs will increase as a result of increased flow losses with consequent requirements for higher head pumps and larger motors. Costs for electrical supply systems will therefore increase.
- Operating costs will increase as a result of higher energy usage due to increased friction losses.

Some costs increase with increasing pipeline size and some decrease. Because of this, an optimum pipeline size may be found, based on minimizing costs over the life of the system.

The duty point of the pump is determined by the intersection of the system curve and the pump curve as shown in Figure 1.

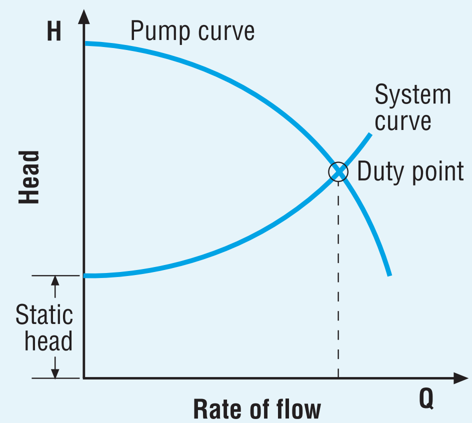


Figure 1. The duty point is the intersection between the pump and system curves

A pump application might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. The pump user must carefully consider the duration of operation at the individual duty points to properly select the number of pumps in the installation and to select output control.
Many software packages are currently available which make it easier to determine friction losses and generate system curves. Most pump manufacturers can recommend software suitable for the intended duty. Different programs may use different methods of predicting friction losses and may give slightly different results. Very often such software is also linked to pump-selection software from that particular manufacturer.

Methods for Analyzing Existing Pumping Systems

The following steps provide an overall guideline to improve an existing pumping system.

- Assemble a complete document inventory of the items in the pumping system.
- Determine the flow rates required for each load in the system.
- Balance the system to meet the required flow rates of each load.
- Minimize system losses needed to balance the flow rates.
- Affect changes to the pump to minimize excessive pump head in the balanced system.
- Identify pumps with high maintenance cost.

One of two methods can be used to analyze existing pumping systems. One consists of observing the operation of the actual piping system, and the second consists of performing detailed calculations using fluid analysis techniques. The first method relies on observations of the operating piping system (pressures, differential pressures, and flow rates), the second deals with creating an accurate mathematical model of the piping system and then calculating the pressures and flow rates within the model.

Observing the operating system allows one to view how the actual system is working, but system operational requirements limit the amount of experimentation that plant management will allow. By developing a model of the piping system, one can easily consider system alternatives, but the model must first be validated to insure that it accurately represents the operating piping system it is trying to emulate. Regardless of the method used, the objective is to gain a clear picture of how the various parts of the system operate and to see where improvements can be made and the system optimized.

The following is a **checklist** of some useful means to reduce the Life Cycle Cost of a pumping system.

- ❏ Consider all relevant costs to determine the Life Cycle Cost
- ❏ Procure pumps and systems using LCC considerations
- ❏ Optimize total cost by considering operational costs and procurement costs
- ❏ Consider the duration of the individual pump duty points
- ❏ Match the equipment to the system needs for maximum benefit
- ❏ Match the pump type to the intended duty
- ❏ Don’t oversize the pump
- ❏ Match the driver type to the intended duty
- ❏ Specify motors to be high efficiency
- ❏ Match the power transmission equipment to the intended duty
- ❏ Evaluate system effectiveness
- ❏ Monitor and sustain the pump and system to maximize benefit
- ❏ Consider the energy wasted using control valves
- ❏ Utilize auxiliary services wisely
- ❏ Optimize preventative maintenance
- ❏ Maintain the internal pump clearances
- ❏ Follow available guidelines regarding the rewinding of motors
- ❏ Analyze existing pump systems for improvement opportunities
- ❏ Use the showcases in the *Guide* as a source for ideas

Example: Pumping System with a Problem Control Valve

In this example the Life Cycle Cost analysis for the piping system is directed at a control valve. The system is a single pump circuit that transports a process fluid containing some solids from a storage tank to a pressurized tank. A heat exchanger heats the fluid, and a control valve regulates the rate of flow into the pressurized tank to 80 cubic meters per hour (m^3/h) (350 gallons per minute [gpm]).

The plant engineer is experiencing problems with a fluid control valve (FCV) that fails due to erosion caused by cavitation. The valve fails every 10 to 12 months at a cost of 4 000 EURO or USD per repair. A change in the control valve is being considered to replace the existing valve with one that can resist cavitation. Before changing out the control valve again, the project engineer wanted to look at other options and perform a Life Cycle Cost analysis on alternative solutions.

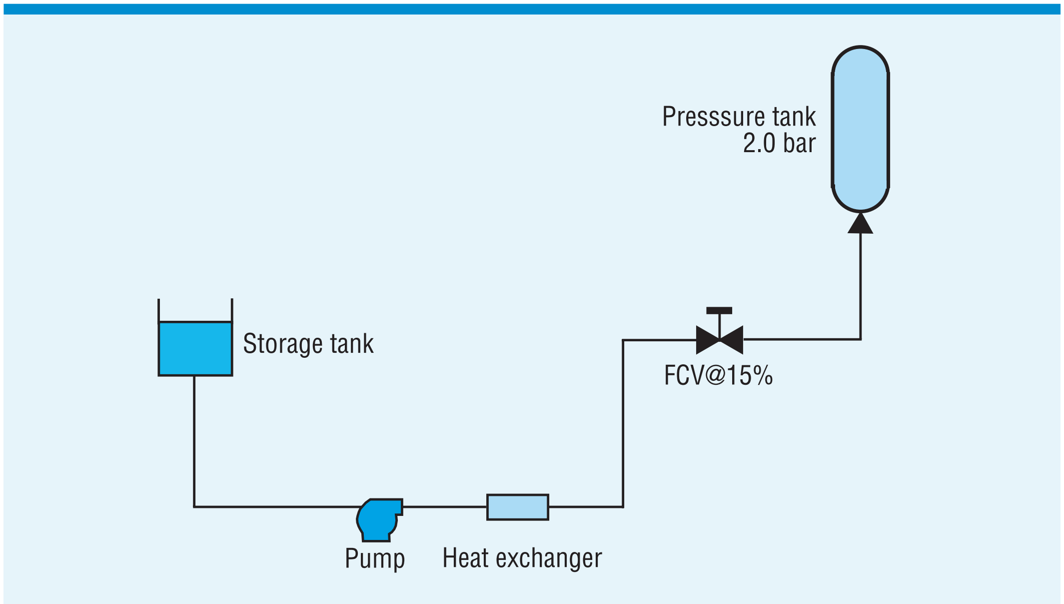


Figure 2. Sketch of pumping system in which the control valve fails

How the System Operates

The first step is to determine how the system is currently operating and determine why the control valve fails, then to see what can be done to correct the problem.

The control valve currently operates between 15-20% open and with considerable cavitation noise from the valve. It appears the valve was not sized properly for the application. After reviewing the original design calculations, it was discovered that the pump was oversized; 110 m^3/h (485 USgpm) instead of 80 m^3/h (350 USgpm), this resulted in a larger pressure drop across the control valve than originally intended.

As a result of the large differential pressure at the operating rate of flow, and the fact that the valve is showing cavitation damage at regular intervals, it is determined that the control valve is not suitable for this process.

The following four options are suggested:

A. A new control valve can be installed to accommodate the high pressure differential.

B. The pump impeller can be trimmed so that the pump does not develop as much head, resulting in a lower pressure drop across the current valve.

C. A variable frequency drive (VFD) can be installed, and the flow control valve removed. The VFD can vary the pump speed and thus achieve the desired process flow.

D. The system can be left as it is, with a yearly repair of the flow control valve to be expected.

The cost of a new control valve that is properly sized is 5 000 Euro or USD. The cost of modifying the pump performance by reduction of the impeller diameter is 2 250 Euro or USD. The process operates at 80 m^3/h for 6,000 h/year. The energy cost is 0.08 Euro or USD per kWh and the motor efficiency is 90%.

The cost comparison of the pump system modification options is contained in Table 1.

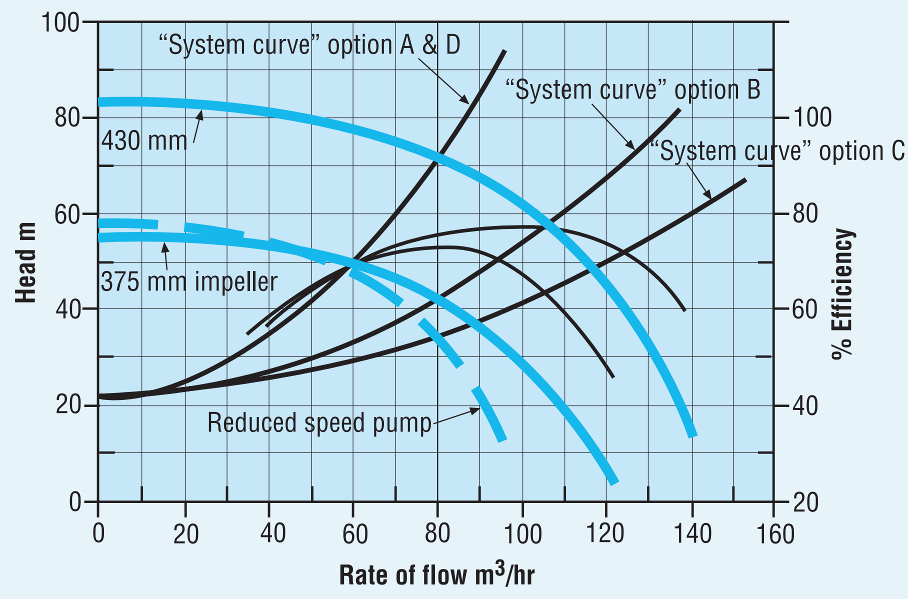


Figure 3. Pump and system curves showing the operation of the original system and the modified pump impeller

Table 1. Cost comparison for Options A through D in the system with a failing control valve

Cost	Change Control Valve (A)	Trim Impeller (B)	VFD (C)	Repair Control Valve (D)
Pump Cost Data				
Impeller diameter	430 mm	375 mm	430 mm	430 mm
Pump head	71.7 m (235 ft)	42.0 m (138 ft)	34.5 m (113 ft)	71.7 m (235 ft)
Pump efficiency	75.1%	72.1%	77%	75.1%
Rate of flow	80 m^3/h (350 USgpm)	80 m^3/h (350 USgpm)	80 m^3/h (350 USgpm)	80 m^3/h (350 USgpm)
Power consumed	23.1 kW	14.0 kW	11.6 kW	23.1 kW
Energy Cost/Year	11 088 EURO or USD	6 720 EURO or USD	5.568 EURO or USD	11 088 EURO or USD
New Valve	5 000 EURO or USD	0	0	0
Modify Impeller	0	2 250 EURO or USD	0	0
VFD	0	0	20 000 EURO or USD	0
Installation of VFD	0	0	1 500 EURO or USD	
Valve Repair/Year	0	0	0	4 000 EURO or USD

By trimming the impeller to 375 mm (Option B), the pump's total head is reduced to 42.0 m (138 ft) at 80 m^3/h. This drop in pressure reduces the differential pressure across the control valve to less than 10m (33 ft), which better matches the valve's original design point. The resulting annual energy cost with the smaller impeller is 6 720 EURO or USD per year. It costs 2 250 EURO or USD to trim the impeller. This includes the machining cost as well as the cost to disassemble and reassemble the pump.

A 30 kW VFD (Option C) costs 20 000 EURO or USD, and an additional 1 500 EURO or USD to install. The VFD will cost 500 EURO or USD to maintain each year. It is assumed that it will not need any repairs over the project's 8-year life.

The option to leave the system unchanged (Option D) will result in a yearly cost of 4 000 EURO or USD for repairs to the cavitating flow control valve.

LCC Costs and Assumptions

- The current energy price is 0.08 EURO or USD /kWh.
- The process is operated for 6,000 hours/year.
- The company has an annual cost for routine maintenance for pumps of this size at 500 EURO or USD per year, with a repair cost of 2 500 EURO or USD every second year.
- There is no decommissioning cost or environmental disposal cost associated with this project.
- This project has an 8-year life.
- The interest rate for new capital projects is 8% and an inflation rate of 4% is expected.

The life cycle cost calculations for each of the four options are summarized in Table 2. Option B, trimming the impeller, has the lowest life cycle cost and is the preferred option for this example.

Table 2. LCC comparison for the problem control valve system

	Option A Change control valve	Option B Trim impeller	Option C VFD and remove control valve	Option D Repair control valve
Input				
Initial investment cost:	5000	2250	21 500	0
Energy price (present) per kWh:	0.080	0.080	0.080	0.080
Weighted average power of equipment in kW:	23.1	14.0	11.6	23.1
Average operating hours/year:	6 000	6 000	6 000	6 000
Energy cost/year (calculated) + Energy price x Weighted average power x Average operating hours/year:	11 088	6 720	5 568	11 088
Maintenance cost (routine maintenance/year:	500	500	1 000	500
Repair every 2nd year:	2 500	2 500	2 500	2 500
Other yearly costs:	0	0	0	4 000
Down time cost/year:	0	0	0	0
Environmental cost:	0	0	0	0
Decommissioning/disposal (Salvage) cost:	0	0	0	0
Life time in years:	8	8	8	8
Interest rate (%):	8.0%	8.0%	8.0%	8.0%
Inflation rate (%):	4.0%	4.0%	4.0%	4.0%
Output				
Present LCC value:	91 827	59 481	74 313	113 930

For More Information

To order *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems*, contact the Hydraulic Institute or Europump.

About the **Hydraulic Institute**
The Hydraulic Institute (HI), established in 1917, is the largest association of pump producers and leading suppliers in North America. HI serves member companies and pump users by providing product standards and forums for the exchange of industry information. HI has been developing pump standards for over 80 years. For information on membership, organization structure, member and user services, and energy and life cycle cost issues, visit *www.pumps.org*.

Hydraulic Institute
9 Sylvan Way
Parsippany, NJ 07054
973-267-9700 (phone)
973-267-9055 (fax)

About **Europump**
Europump, established in 1960, acts as spokesman for 15 national pump manufacturing associations in Europe and represents more than 400 manufacturers. Europump serves and promotes the European pump industry. For information regarding Europump work in the field of life cycle cost issues, please email: secretariat@europump.org. For information on Europump, visit *www.europump.org*.

Europump
Diamant Building, 5th Floor
Blvd. A Reyers 80, B1030
Brussels, Belgium
+32 2 706 82 30 (phone)
+32 2 706 82 50 (fax)

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U.S. Department of Energy
Office of Industrial Technologies
1000 Independence Avenue, SW
Washington, DC 20585
clearinghouse@ee.doe.gov
1-800-862-2086

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