WORLD PUMPS February 2010

Pump selection

Centrifugal pump selection process

Centrifugal pumps can be used in many applications, but in order to operate reliably, with optimal energy use and maximum life span, a pump's design characteristics must suit the intended service. Correct pump selection is the first step to ensure this, as Eduardo Larralde and Rafael Ocampo demonstrate in this first of two articles.

Operational versatility is an outstanding feature of centrifugal pumps that has contributed to their extended use in a wide range of applications. But, although a centrifugal pump can serve many different operating conditions, it will not provide suitable and satisfactory performance in all of them.

In order for a pump to run correctly, without wasting energy or sustaining internal damage, its design characteristics must be suitable for the intended service. Therefore, the correct selection of the pump is the first step in guaranteeing efficient and appropriate performance, reliable operation and a reasonably long life span.

In spite of the existence of a large volume of literature concerning the selection of pumps, there are still essential aspects that are sometimes overlooked, leading to an inadequate selection. The main purpose of this article is to review the most important technological details to be defined before seeking a quotation for a new centrifugal pump, the aspects to be included in the enquiry and those to be carefully checked in the offers received before taking the decision as to which is the best pump to fulfil the required service.

Preliminary definitions

The initial selection process for any pump should include the following steps:

1. Definition of the technological process outline and main process parameters such as flow, pressure and temperature.

2. Determination of the required pumping services.

3. Complete description of the fluid to be handled in each pumping service (type of fluid, temperature, density, viscosity, corrosiveness, erosiveness, vapour pressure, solids in suspension, toxicity, volatility).

4. Plot of general layout of the plant and determination of available space in three dimensions.

5. General arrangement and dimensions of the piping according to the recommended velocities for each fluid and type of pipe.

6. Determination of elevation for suction and discharge points or vessels relative to the centre line of the pump.

7. Preliminary calculation of friction losses and plotting of system characteristic curve. Consider allowance for future corrosion of pipes.

8. Definition of the working parameters of the pump, namely, capacity, head, suction and discharge pressures, taking into account any possibility of variations in pressure or temperature at different pumping conditions.

9. Determination of any possible exceptional start, stop or running conditions.

10. Determination of available NPSH.

11. Preliminary selection of the pump type, design, position, driver, type of sealing, and cooling of seal and bearings if required.

12. Determination of the type of drive unit (electric motor, steam turbine, etc.) and its main operating parameters. In the case of an electric motor, special attention should be paid to its efficiency (only high-efficiency motors should be specified) and to the advisability of using a variable speed drive (VSD).

In the authors' experience, the buyer should take the preliminary definitions highlighted in item 11 and include them in the technical specifications of the bid request sent to the suppliers. This action should not eliminate the possibility and advisability of communication and exchange of criteria between buyer and seller leading to mutually agreed changes.

After gathering all the information outlined in the 12 items listed above, the buyer will be ready to prepare the specifications for the quotation request. According to the API 610 standard[1], a good practice is to fill in as much information as possible in the data sheet shown in its appendix. Undoubtedly, this data sheet is a valuable document for pump owners, which is why its length has increased from one page in the Fifth

Edition (March 1971) to five pages in the Eighth Edition (August 1995).

The first box shows the data that must be included in the technical specification. The data shown relate to an actual pump whose selection will be discussed in the case study to be presented in the second article in this two-part series. The second box shows the required scope of supply.

Nevertheless, the previously listed information is not enough. Operational requirements are of the upmost importance, and therefore should be defined with the maximum accuracy. Frequently, capacity and head are established only for normal and maximum values without taking into account that the pump could run through a wide range of capacities and that the process may not allow pressure differences beyond certain limits. This is just the case in the example to be presented in the next article. This condition will obviously force an arrangement to be found to fulfil that basic requirement with the highest possible efficiency. Several options could be considered, such as choosing a pump whose Q-H (capacity–head) characteristic curve is flat enough to satisfy the conditions imposed by the process; using several pumps in parallel; or using a VSD.

It may happen that the option adopted entails the pump running in a capacity range wider than the recommended 80% – 110% of the flow at the best efficiency point (BEP), losing not only efficiency but also reliability, as shown in Figure 1[2].

Additionally, the minimum safe flow recommended by the manufacturer for the pump should be clearly stated in order to prepare the system to ensure the safe, continuous operation of the pump when the process flow demand is lower than that value.

Bid analysis

At this point the buyer is ready to ask for preliminary offers in order to carry out a thorough analysis of the characteristic curves of the offered pumps and, of course, a detailed check of all the other information contained in the offers. When checking the characteristic curves there are three main aspects to consider.

Firstly, the API 610 standard must be fulfilled concerning the supply of all the required curves, namely, differential head, efficiency, NPSH(R) and power consumption, all of them plotted against the capacity of the pump. The scope of these curves should cover at least up to 125% of the pump capacity at the BEP. Additionally, head–capacity curves for minimum and maximum impeller diameters should be shown. The necessary corrections for viscosity should be clearly indicated. The area of flow for the eye of the first-stage impeller as well as its identity number should also be shown. Although the API 610 standard requires the inclusion of these data for the first-stage impeller in the characteristic curves, it should be pointed out that only a few manufacturers do so and therefore this information will have to be insisted on by the buyer. The worst case is when the supplier fails to include the efficiency curve or the NPSH(R) curve, which is completely unacceptable if a correct selection of the pump is to be made.

Secondly, the rotational speed, density and viscosity to which the curves relate must be taken into consideration. If they do not match up with the data in the bid request it will be necessary to do the pertinent corrections. Failure to do this detailed checking can cause misunderstandings, leading to mistakes. A common problem for electrically driven pumps occurs when the pump is to be installed in a country using a different electric voltage and/or frequency from that used in the country of the manufacturer.

Lastly, the actual efficiency occurring at the operating point of the pump and the maximum efficiency the pump can achieve should be compared; unreasonably large differences should not be allowed. This comparison is made by intersecting the system characteristic curve with the pump's head curve in order to establish what the operating point of the pump will be and compare it with the BEP. As mentioned before, it is recommended that the pump run between 80% and 110% of the capacity at the BEP. Overlooking this important detail leads to a significant energy loss. Many pump users do not realize that the cost of energy can represent between 30% and 90% of the life cycle cost (LCC) of the pump[3–6]. The curves shown in Figure 2 and the pie chart in Figure 3 clearly illustrate this fact. According to process variations, a pump service might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. The engineer in charge of pump selection must carefully consider the duration of operation at each duty point to select properly the number of pumps and the control system to use.

In order to carry out a thorough analysis and correctly select the pump it is advisable to obtain complete information from the supplier about the full range of pump models, rotational speeds and impeller diameters as well as the characteristic curves for all the proposed pumps. The suppliers should be consulted during the bid analysis in order to clarify every detail and ensure the selection of the best pump model.

Selection and acquisition

After fulfilling all the preliminary steps and obtaining all the aforementioned information, the buyer can ask for final offers for the pump models that best fit the requirements. Comparisons between offers will then be made focusing on aspects such as the purchase price, the payment conditions and facilities, the time for delivery, the guarantee for spare parts supply over a reasonably long period, the prestige of the manufacturer and its references. It is good practice to contact previous buyers of the same or a similar pump type to get information about its behaviour.

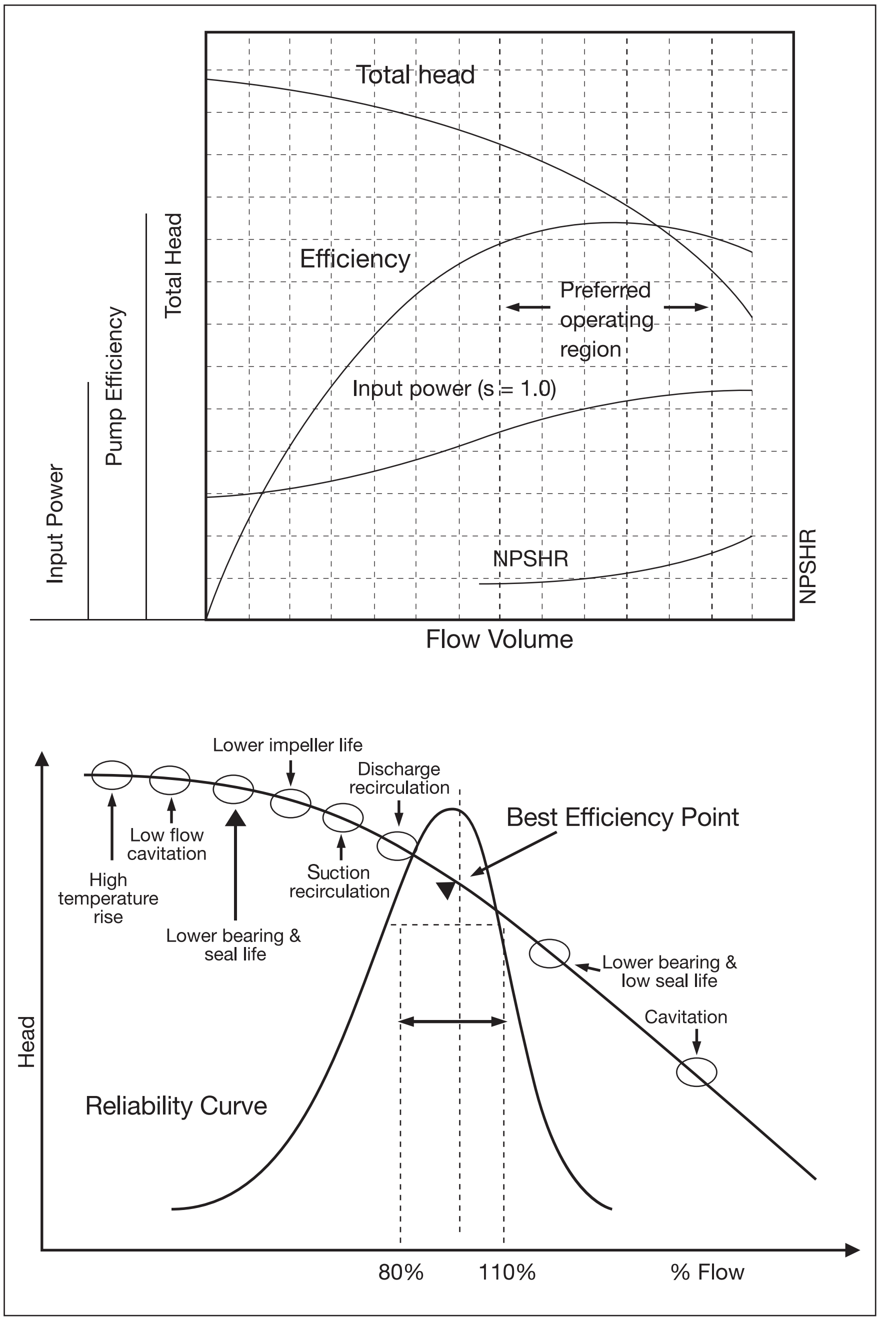

Figure 1. Adverse effects of operating away from the BEP (reproduced from Ref. 2, courtesy of Allweiler AG).

From both the engineering and economical standpoints, the efficiency of the pump–motor set is of the upmost importance. The selection of pump and motor should ensure high efficiency values, aiming for the lowest possible energy consumption per volume of pumped fluid. It is very convenient (sometimes mandatory) to choose high-efficiency motors, whose initial cost is higher, but that reimburse the expense through the saving in energy consumption in the long run. Nowadays, some authors consider that a low-efficiency motor is too expensive even if it is free[7]. The decisions taken concerning efficiency and energy saving will have an influence not only on the LCC of the pump–motor set but also in reducing carbon dioxide emissions to the atmosphere.

Pump owners should be aware that selecting efficient pumps and motors alone is not enough to achieve cost-effective and reliable operation. The pump characteristics must properly fit the system requirements throughout the variations occurring in the process, ensuring operation as close as possible to the BEP for the majority of the operating time.

Operating a pump away from its BEP can cause adverse effects such as cavitation, shortening of the life of seals, impellers and bearings, internal fluid recirculation and internal heating. On the other hand, running a pump at or close to its BEP avoids those

Minimum specifications required for pump quotation request

Service: hot water circulating pumps

Type of pump: centrifugal.

Preferred position of the shaft: horizontal.

Fluid: treated water, pH: 9.5

Corrosive/erosive agent: no.

Normal pumping temperature: 185°C; maximum: 195°C.

Density at pumping temperature: 881 kg/m^3.

Viscosity at pumping temperature: 1.68 x 10^{-7} m^2/s.

Vapour pressure at pumping temperature: 1.123 MPa.

Normal capacity at pumping temperature: 105 m^3/h.

Rated capacity at pumping temperature: 120 m^3/h.

Minimum operating flow: 45 m^3/h.

Rated differential head (water at 20°C): 111.3 m.

Rated differential head (corrected for the density): 126.3 m.

Maximum suction pressure: 1.37 MPa (from a pressurized vessel).

Discharge pressure: 2.46 MPa.

Maximum discharge pressure allowed by the process: 2.58 MPa.

NPSH available: 20 m.

Preferred rotational speed: 3500 rpm.

Shaft sealing: packing.

Seal cooling: yes.

Bearing cooling: yes.

Cooling fluid available: treated water, 35°C.

Construction materials: according to the manufacturing standards taking into account the pump design and operating conditions indicated above.

Drive: electric motor with the following features:

- Phases: 3
- Start: delta-star.
- Voltage: 760/440 V; voltage tolerance: ±10%
- Frequency: 60 Hz; frequency tolerance: ±4%
- Efficiency class: EFF 1
- Minimum protection: IP 55 for tropical conditions.
- Type of service: continuous, industrial, heavy.
- Operating conditions: 24 hours/day, 6 days/week.
- Starting: not less than 3 starts per hour. Interval between starts could be as short as 30 seconds.
- Power: suitable for the whole Q-H curve of the pump.

Environmental conditions:

- Maximum temperature: 40°C.
- Minimum temperature: 10°C.
- Relative humidity: 85%.
- Altitude: 100 m above sea level.
- Location of installation: under shed, without walls.

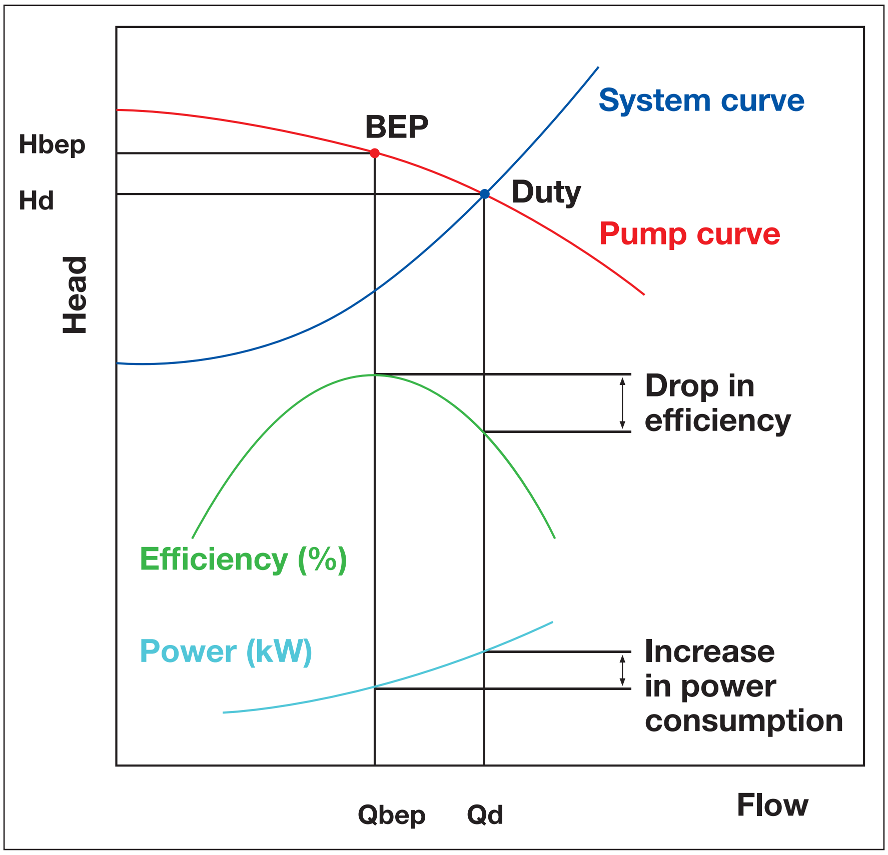

Figure 2. Efficiency drop versus capacity.

Scope of supply

Pump.

Induction electric motor (with VSD if required).

Steel base plate, common to pump and motor.

Flexible coupling.

Protection of mobile parts.

Counter flanges, neck type UNI/DIN for welding to ANSI Schedule 40 pipes.

Technical documentation, which should include: complete data sheets for pump and driver as stated by API 610; drawings and specifications for driver, coupling and pump; materials specifications; characteristic curves; installation, operation and maintenance instructions; lubrication instructions; spare parts recommendations; and so on.

Inspection and testing certificates as per the scope stated by API 610.

problems and therefore increases its reliability (Figure 1).

Nowadays, the increase in the costs associated with running a pump, mainly the cost of energy, has made the initial cost less important when compared with the LCC of the pump, making the LCC calculation an indispensable tool to be used for the acquisition of any type of pump. After the full selection process described has been completed, the final selection of the pump can be made.

Other considerations

Besides the selection of the pump itself there are some points worth considering. Shop inspection and testing of the pumps must fulfil the standards regarding the type of test to be made, the correct application of the test procedure and the handing over of the resulting test data. More frequently than is desirable, some manufacturers submit scant information on tests results. Depending on the quantity and importance of the equipment being bought, the buyer should assess the practicality of his personnel or hired technicians participating in the shop inspection and testing of the pumps.

The buyer should confirm that the standard applied for manufacture and testing is a recognized international standard and should check it and verify that it satisfies requirements.

In the second article a case study will be discussed, applying all the procedures outlined here and explaining the decision-making process. ■

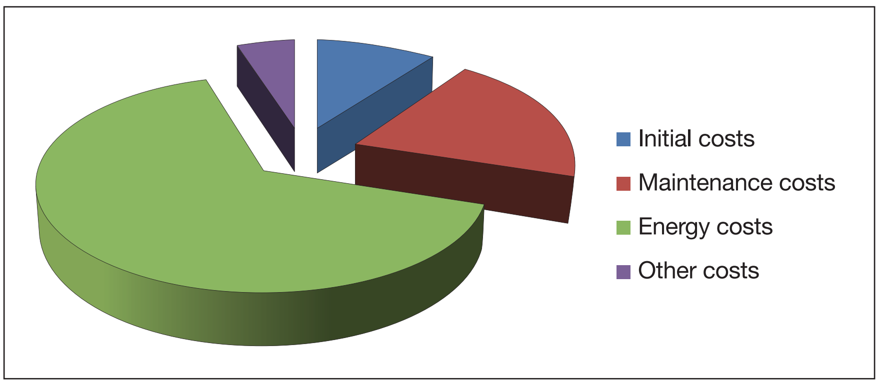

Figure 3. Typical breakdown of pump costs.

References

[1] API 610, 'Centrifugal Pumps for Petroleum, Heavy Duty Chemical and Gas Industry Services', Eighth Edition, American Petroleum Institute, (1995).

[2] E. Braun and W. Leiber, 'The right pump lowers total cost of ownership', *World Pumps*, No. 491, pp. 30–33, (2007).

[3] B. Went, 'The systems approach to reducing carbon emissions', *World Pumps*, No. 500, pp. 52–55, (2008).

[4] L. Dingley, 'Will sustainability end up costing the earth?', *World Pumps*, No. 494, pp. 26–28, (2007).

[5] P. Noll, 'Determining the real cost of powering a pump', *World Pumps*, No. 496, pp. 32–34, (2008).

[6] M. Cieslak, 'Life cycle costs of pumping stations', *World Pumps*, No. 505, pp. 30–33, (2008).

[7] H-J. Bittermann, 'Germany makes strides into energy efficiency', *World Pumps*, No. 493, pp. 36–39, (2007).

Contact
Eduardo Larralde
E-mail: larralde@quimica.minbas.cu

Rafael Ocampo
E-mail: rocampod@gmail.com