water solutions

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Guide to the selection of **UNIQA**® electricpumps

INTRODUCTION

The introduction of **UNIQA**® pumps requires sales technicians and resellers to be able to select and explain their constructional and functional characteristics. They must therefore be familiar with the basic technical concepts applicable to all pumps, as well as those which apply specifically to the **UNIQA**® range:

- Basic concepts of hydraulics
- Q-H curve (duty point)
- Pump - Motor (P1 - P2 - P3)
- Efficiency
- Concept of hydraulics
- Applying motors of various power ratings to a given impeller
- Operation with frequency variator
- Other selection criteria (materials, versions, etc.)

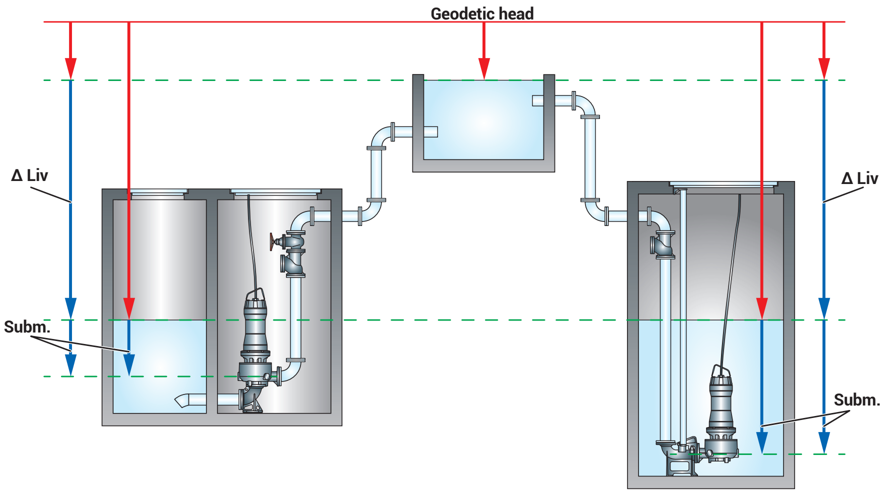
1. BASIC CONCEPTS OF HYDRAULICS

1.1 Flow rate (Q)

The volume of fluid transported in a unit of time: Q (m^3/s ; m^3/h; l/s ecc...)

1.2 Geodetic head (Hg)

The geodetic head (also known as static head or geodetic differential) is defined as the **pressure differential between the fluid discharge and suction**. Although the definition is simple, it can often be interpreted incorrectly, leading to selection of the wrong pump. The following example should clarify the concept.



Given the definition of "geodetic head", for both systems the following applies:

Hg = discharge pressure - suction pressure

where:

Discharge pressure = atmospheric pressure + **Δ** level + submergence

Suction pressure = atmospheric pressure + submergence

Then:

Hg = atmospheric pressure + **Δ** level + submergence - (atmospheric pressure + submergence)

Semplifying:

Hg = ~~atmospheric pressure~~ + **Δ** level+ ~~submergence~~ - ~~atmospheric pressure~~ - ~~submergence~~

Hg = Δ Livello

The two systems in the example, although their pumps are installed at different depths, have the same geodetic head.

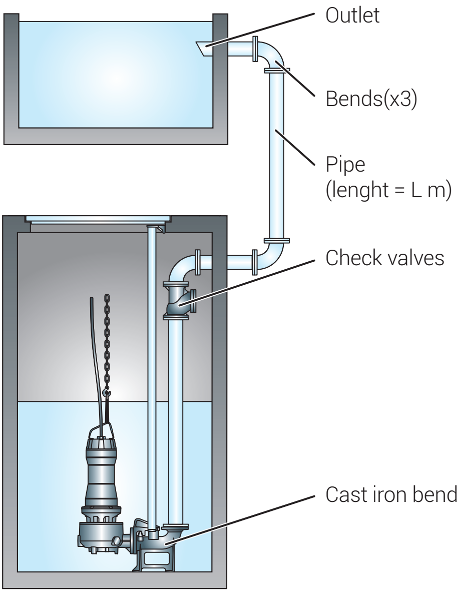
1.3 Pressure drop (Hv)

The pressure drop is the energy loss due to friction and turbulence caused by the movement of the fluid and the configuration of the hydraulic circuit, and is represented by the following generic equation

$$Hv = K \times v^2/2g$$

where:

Hv= pressure drop of circuit (m); **K=** pressure drop coefficient of circuit. It is a constant, equal to the sum of the empirical coefficients of each element generating a pressure drop; **v=** water speed; **g=** gravitational acceleration (m/s²). Example:



$Hv_5 = K_5 \times v^2/2g$

$Hv_3 = \underbrace{3 \times K_3}_{K_3} \times v^2/2g$

$Hv_4 = \underbrace{L \times K_4}_{K_4} \times v2/2g$

$Hv_2 = K_2 \times v^2/2g$

$Hv_1 = K_1 \times v^2/2g$

K1 … K5= specific pressure drop coefficients of each element (available in hydraulics manuals/texts).

The pressure drop of the circuit as a whole is the sum of the individual pressure drops:

$$Hv_{TOT} = Hv_1+Hv_2+Hv_3+Hv_4+Hv_5$$

at constant speed:

$$Hv_{TOT} = K_1 \times v^2/2g + K_2 \times v^2/2g + K_3 \times v^2/2g + K_4 \times v^2/2g + K_5 \times v^2/2g$$

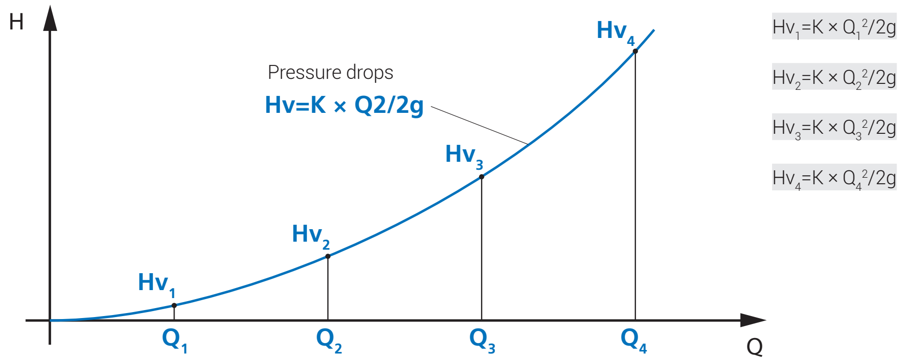
$$Hv_{TOT} = (K_1+K_2+K_3+K_4+K_5) \times v^2/2g$$

$$Hv_{TOT} = K \times v^2/2g$$

For a given hydraulic circuit, the speed is directly proportional to the flow rate, so that the pressure drop in that circuit can also be expressed as

$$Hv_{TOT} = K_Q \times Q^2/2g$$

For each circuit, the pressure drop varies with the flow rate and can be represented in a Q-H diagram by calculating Hv over a range of flow rates and tracing the curve over the resulting points:



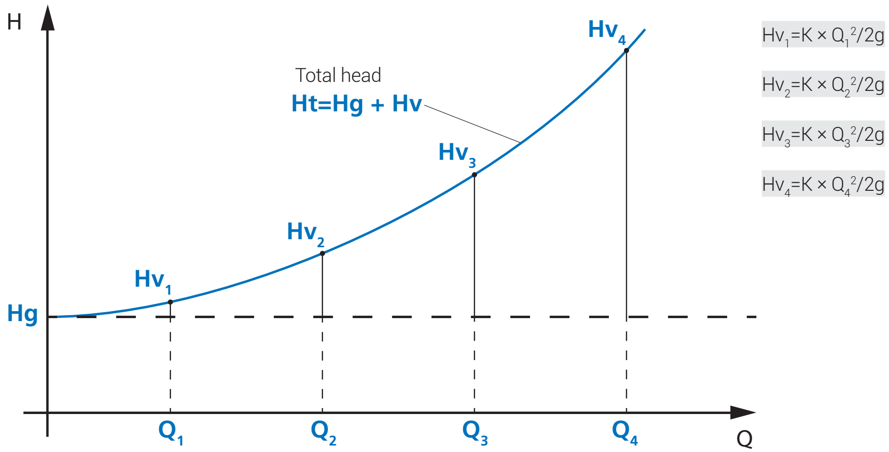
1.4 Total head (Ht)

This is the pressure that the pump must overcome to create a flow Q from one point to another, and is equal to the sum of the static pressure, **geodetic head (Hg)**, and the dynamic pressure, **pressure drop (Hv)**. The most common unit of measurement is the water column metre (m), but other units may also be used (bar, psi, Pascal, etc.)

$$Ht\ (m) = Hg\ (m) + Hv\ (m)$$

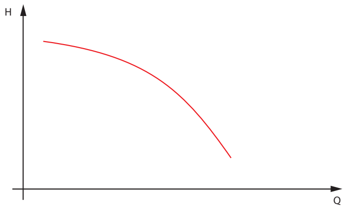
where for a given hydraulic circuit, Hg is constant while Hv depends on the flow rate (see points 3.2 and 3.3).

The total head is represented as follows:

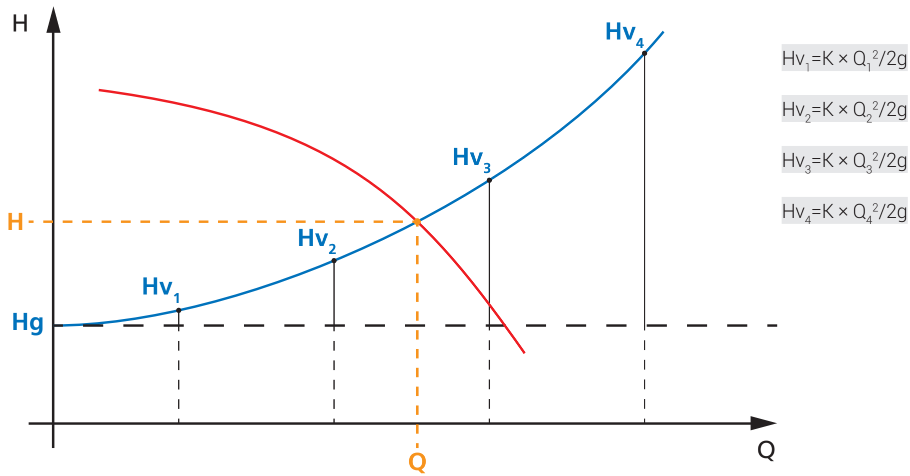


2. DUTY POINT

As is known, the flow rate of centrifugal pumps is not constant like that of volumetric pumps, but rather varies with the pressure (head) they have to overcome.
The performance of a centrifugal pump is given by Q as a function of H.

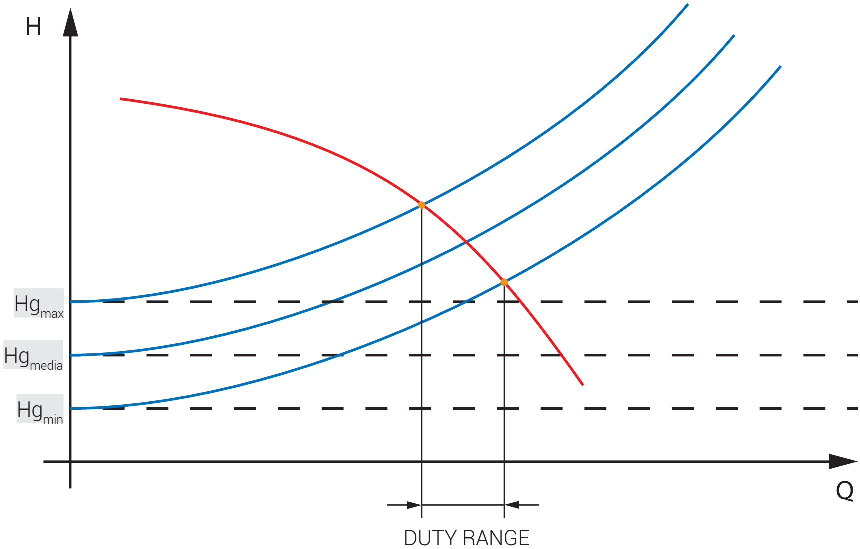


The duty point (Q and H) of a pump in a given circuit is given by the intersection of the characteristic curve with the total circuit head curve:



2.1 Hg variance - duty range

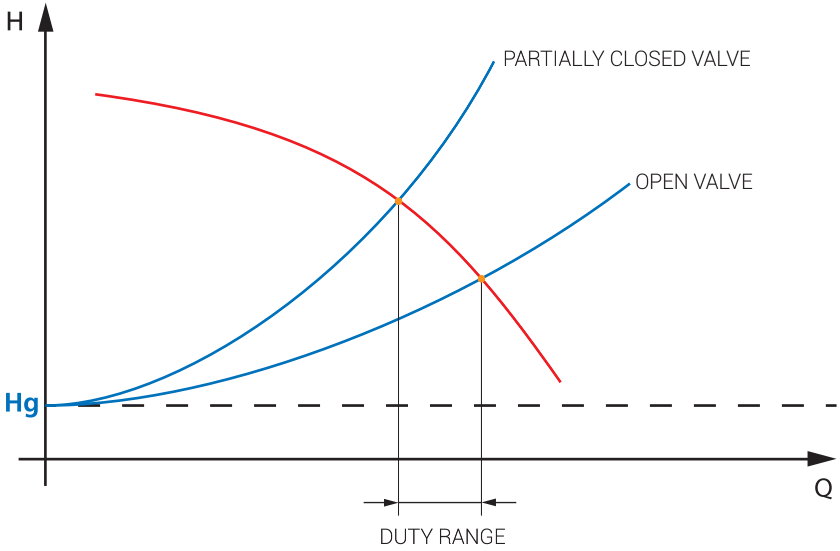
In most cases, sewer pumps are installed in sumps, the level of which varies from a maximum at start up to a minimum (stopped). The pump does not therefore work at a single duty point, but rather in a range represented by a section of the characteristic curve. To select a pump correctly, one must take into account the entire duty range, and not just a single point of it.



As the geodetic head varies, the pressure drop curve remains the same, but shifts up or down with the geodetic head.
The resulting duty points bound the pump's effective duty range for the circuit in question.

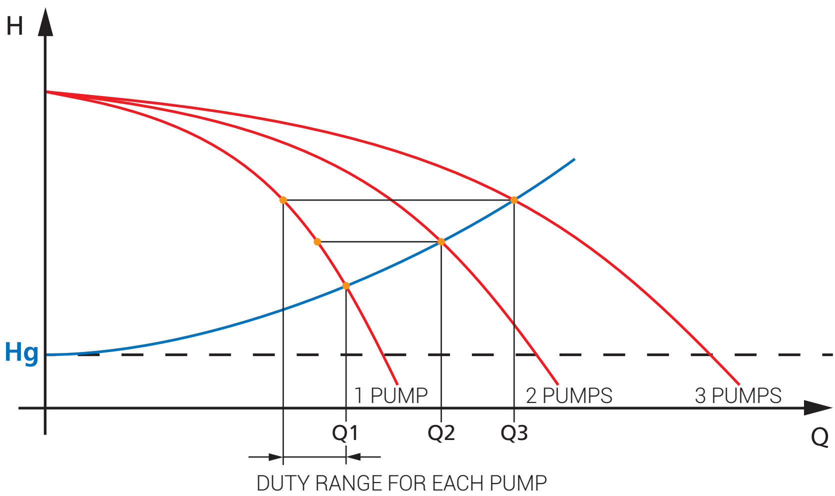
2.2 Hv variance - duty range

The pressure drop curve is normally constant. However, it may occur that it varies, for instance when the flow rate is regulated by a valve or the pipes are partially blocked. Closing or opening a regulator valve simply increases/reduces the pressure drop.



2.3 Pumps working in parallel - duty range

When several pumps are working in parallel, the duty point of each pump changes according to the number of pumps operating at any time.



3. PUMP - MOTOR

While small integrated electric pumps are generally used for domestic applications, in the case of larger pumps one must consider the motor and pump separately. This distinction is also critical to the concepts of P1, P2, P3, hydraulic efficiency and total efficiency.

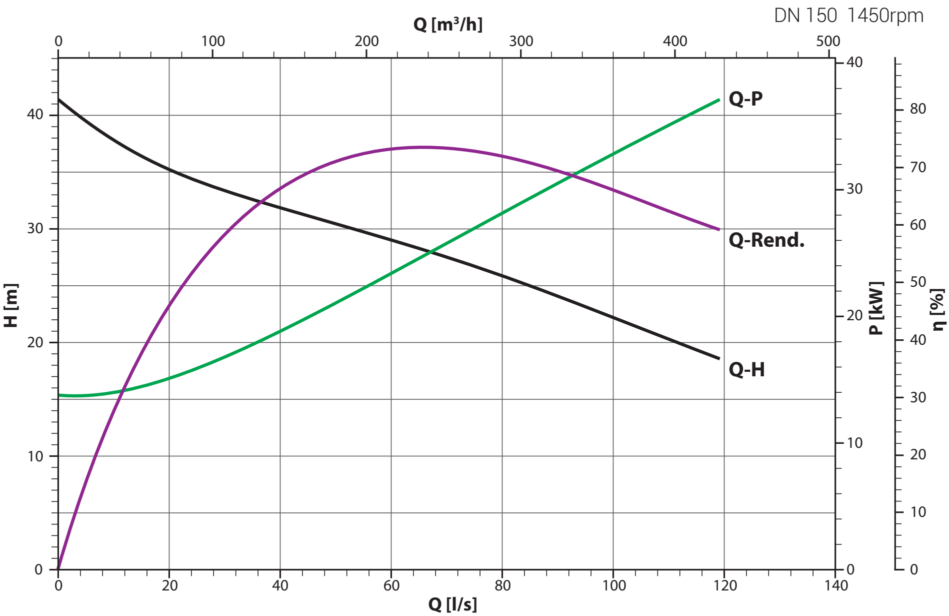
3.1 Pump

The "pump body" and "impeller" constitute the pump assembly, ready for coupling to a motor.

Conventional pump for coupling between base and union

Pump for direct coupling to submersible motor

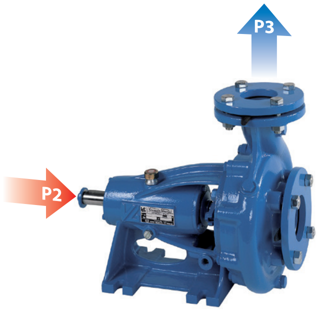
Any pump is characterised by its suction and discharge diameters and the characteristic curve which determines its performance at a given rotary speed:



The image shows the characteristic curve of a DN 150 pump operating at 1450 rpm.

- **Q-H curve:** gives the flow rate or a given head **H**;
- **Q-P curve:** gives the power required (and which must therefore be supplied to the pump) to provide a given duty point Q-H. This power is called **P2**;
- **Q-Efficiency curve:** gives the ratio between the power draw of the pump **(P2)** and the powe delivered to the fluid **(P3)**, called the "hydraulic efficiency" η_{idr} o **Eta**$_{idr}$.

P3 - P2 - Hydraulic efficiency



P3 is the power delivered to the fluid:

$$P3\ (W) = Q(l/s) \times \boldsymbol{\gamma}\ (Kg/l) \times 9.81(m/s^2) \times H(m)$$

For water

$$(\boldsymbol{\gamma} = 1\ Kg/l):\ P3\ (W) = Q(l/s) \times 9.81(m/s^2) \times H(m)$$

or, using other units:

$$P3\ (kW) = Q(l/s)\ /\ 1000(l/m^3) \times 9.81(m/s^2) \times H(m) = Q(l/s)\ /\ 1000(l/m^3) \times 9.81(m/s2) \times H(m)$$

$$P3(kW) = \frac{Q(l/s) \times H(m)}{102}$$

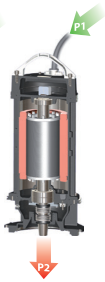
(1000/9,81=101,9367)

$$\eta_{idr} = \frac{Q \times H}{102 \times P2}$$

P2 is the power required for the pump to deliver a flow rate of Q with a head H, i.e. P3. The ratio between P3 and P2 **is the efficiency of the pump, or hydraulic efficiency (η_{idr})**.

3.2 Motor

Electric motors, along with their speed, absorption, torque, etc., are characterised by their power delivery and power draw.



P1 - P2 - Efficiency

P2 is the motor's power delivery. The motor does not deliver constant power, but rather the power demanded by the machine coupled to its shaft. E.g.:

If the shaft is uncoupled P2 = 0 → the motor is running under "no load"

If the motor is coupled to a machine with a power draw of 10 kW, P2= 10 kW, and the following three cases are possible:

- The motor's power rating is > 10 kW → the motor is running at "partial load"
- The motor's power rating is = 10 kW → the motor is running at "full load"
- The motor's power rating is < 10 kW → the motor is "overloaded"

P1 is the power drawn by the motor from the mains to deliver P2.

$$P1 = \frac{V \times I \times \cos\varphi \times \sqrt{3}}{1000}$$

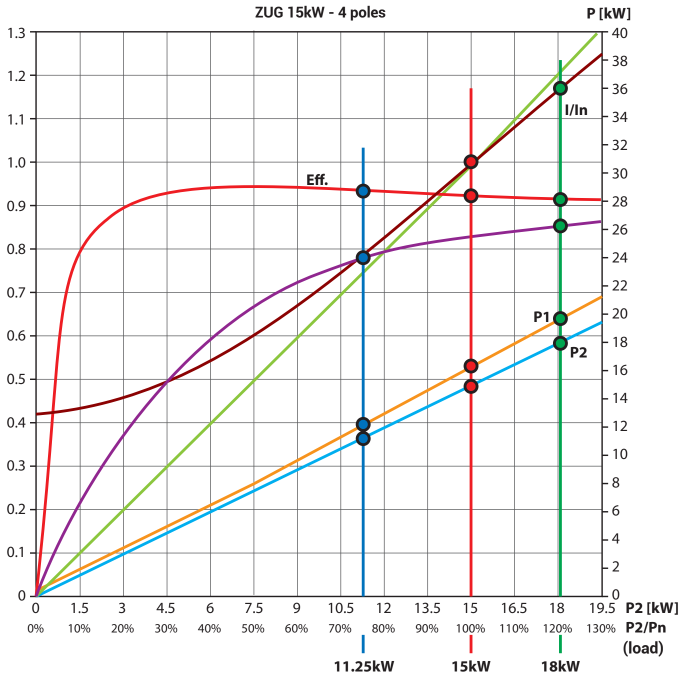
V = Voltage (V); I = Current (A)

The ratio of P2 to P1 is the efficiency of the motor:

$$\eta = \frac{P2}{P1}$$

3.2.1 Motor - duty point - power rating

Once powered up, an electric motor tends to supply the power demanded by the machine coupled to its shaft, and so the performance of the motor is represented by the curves of its various parameters as a function of the load. We give below the graph for the ZUG 15/4 motor, giving the curves of all parameters in relation to the load.



Rated power

As can be seen from the diagram, the motor can deliver P2 in the range 0 to 19.5 kW (theorically, it could even exceed this value).
It can also be seen that the power draw increases with the power delivery. The heating of the motor depends on its draw and increases exponentially with the latter. Depending on the maximum permitted temperature (related to the type of insulation and the service life, reliability, efficiency, etc. to obtain), the motor's duty range is limited to a maximum value of P2 called the nominal power or power rating, to which the nominal values of P1, I, etc. correspond.

Duty point

As noted above, depending on the applied load, the motor can operate at a variety of points, of which we consider 3 as examples:

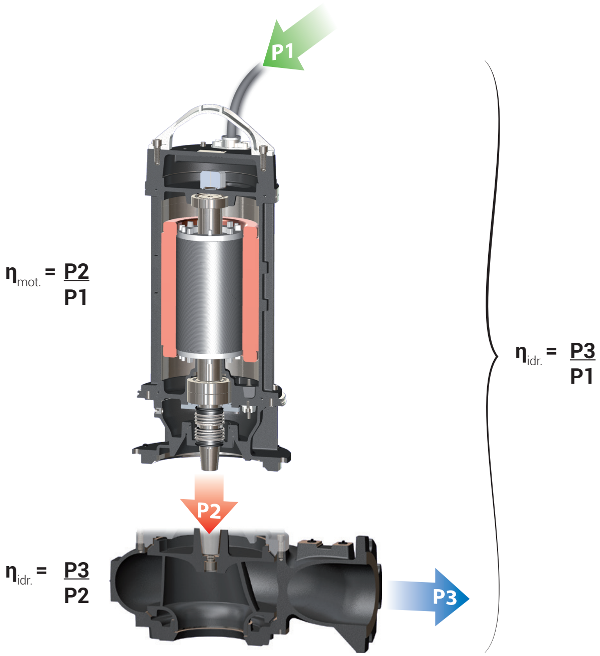
P2 = 11.25 kW **P1 = 12.07 kW** **I = 22.5 A** **η = 93.18%**
In this case, the motor is loaded below its nominal power. It will heat up less than its design limit, and its service life may thus be longer than the theoretical value.

P2 = 15 kW **P1 = 16.27 kW** **I = 22.5 A** **η = 93.18%**
The motor is operating at its nominal load and hence to its design specification

P2 = 18 kW **P1 = 20 kW** **I = 31.7 A** **η = 91.5%**
Working beyond its nominal load the motor is therefore overloaded. The temperature is higher than the design limit and hence its service life will be shorter, if it doesn't burn out immediately. To prevent this the motor is protected by a cutout which stops it when the power draw exceeds the nominal value.

3.3 Pump/motor assembly - total efficiency

Especially for integrated electric pumps, like submersible pumps, along with the concepts of pump and motor efficiency, we must also consider the total efficiency of the machine as a whole.



Considering the pump alone, one compares the hydraulic efficiency, and for the motor, the motor efficiency. If, on the other hand, one is considering an integrated machine like a submersible pump, the correct parameter to consider is the total efficiency.

E.g.: one requires an electric pump with a flow rate of 100 l/s at 10 m to pump 8000 m³/day, 365 days/year

1) Pump efficiency= 80% → Motor efficiency = 80%

$$P2 = \frac{100 \times 10}{1{,}02 \times 80} = 12{,}25 \text{ kW} \qquad P1 = \frac{12{,}25}{0{,}8} = 15{,}3 \text{ kW}$$

$$\text{Energy consumption} = \frac{8000}{100 \times 3{,}6} \times 15{,}3 \times 365 = 124.100 \text{ kWh/year}$$

2) Pump efficiency= 75% Motor efficiency = 92%

$$P2 = \frac{100 \times 10}{1{,}02 \times 75} = 13{,}07 \text{ kW} \qquad P1 = \frac{13{,}07}{0{,}92} = 14{,}2 \text{ kW}$$

$$\text{Energy consumption} = \frac{8000}{100 \times 3{,}6} \times 14{,}2 \times 365 = 115.178 \text{ kWh/year}$$

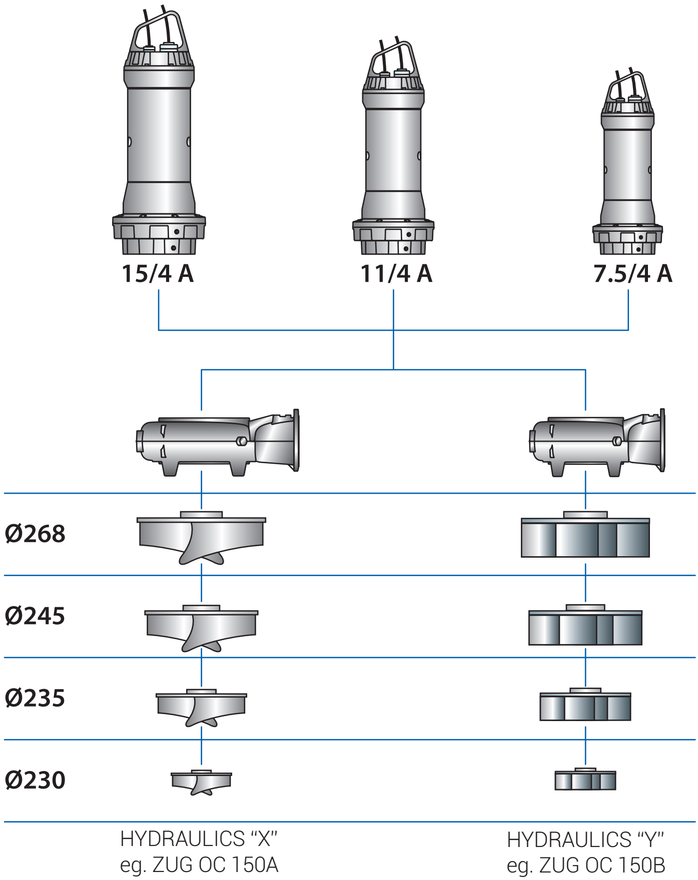
In the second case, the annual consumption is around 9000 kWh less, **even starting from a pump with a lower hydraulic efficiency, due to the higher motor efficiency of the machine**.

From the above, it is evident that **the optimal solution is a combination of the most efficient possible pump and motor.**

UNIQA® pumps, however, are intended for use in sewers for pumping unstrained waste water. Along with the efficiency, one must therefore also consider the operational reliability, with special attention to potential blockage by large objects. For this reason, we have compromised by combining the most efficient hydraulics, but with a minimum free passage of 80 mm, with high efficiency motors in class IE3.

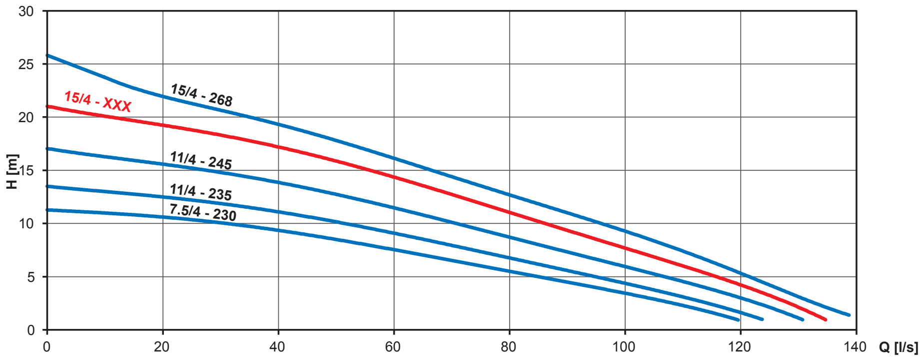
4. UNIQA® - MODULAR CONSTRUCTION

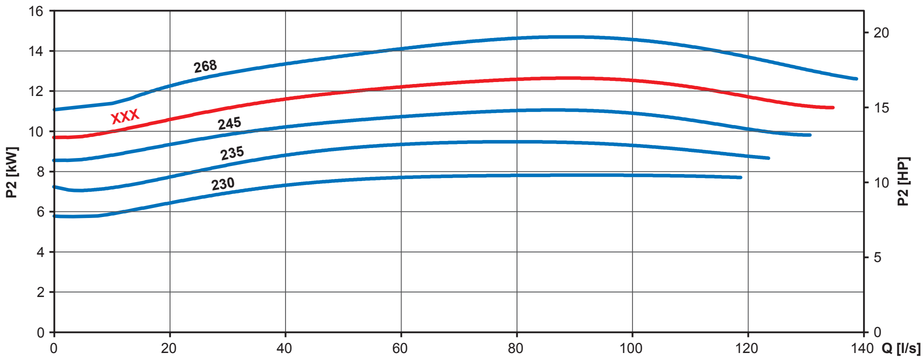
The modular construction concept, by now employed by many manufacturers, has been used in the design of the **UNIQA**® series. The aim is to provide the client with a large number of pump/motor combinations, so as to cover a vast range of performance requirements with the most appropriate pump.
In practice, this means that it is possible to install motors of various powers and speeds to a given hydraulic module, as well as impellers of various diameters. The same motors can also be used with other hydraulic modules.



The figure shows how hydraulic unit ZUG OC 150A can be fitted with impellers of diameter 268, 245, 235 and 230, and can mount 3 different 4-pole motors, rated from 7.5 to 15 kW.

The characteristic curve of the ZUG OC 150A represents the curves of all impellers and the standard motors used with them:





Note - the red curve does not exist. It has only been included as an example

In the normal representation, the curves of the various impellers are shown with their standard motors, which is the one whose power covers the entire curve.
For special requirements, one can select another motor, so long as its power covers the section of characteristic curve in which the pump is intended to operate

E.g.:
Motor 15/4 can be used with impeller 245.

In this case, the maximum applied P2 will be somewhat less than 11 kW, so that the motor will not heat up very much and will therefore last longer, or will be able to work in water at higher than 40°C or with fluids of greater density than water and hence a higher P2 requirements, and in any case in all situations in which overloading is likely and thus a power margin is required.

Motor 11/4 can be mounted to impeller xxx so long as you are certain that the duty range is between 0 and 40 l/s.

In this case, the part of the curve beyond 40 l/s will be shown dashed. It is normally not worth using this option for moderately sized pumps (up to 30 kW or so), but it is advisable and even necessary for larger power applications.

U5.UNIQA® - OPERATION WITH VARIABLE FREQUENCY DRIVES

All pumps, including old ZENIT production, can operate with variable frequency drives. However, **UNIQA**® pumps are specially designed to do so. In particular, the motors employ materials and dimensions for this purpose.

5.1 Operating Principle

The pump's power supply when using a variable frequency drive enables the impeller speed to be varied and hence shifts the Q-H, Q-P2 and Q-P1 curves up and down. As the frequency changes:

- The rotational speed is directly proportional to the ratio between the frequencies
- The flow rate is directly proportional to the speed variation
- The head varies with the square of the speed variation
- The power varies with the cube of the speed variation
- The hydraulic efficiency remains the same

E.g.:

At 50 Hz:

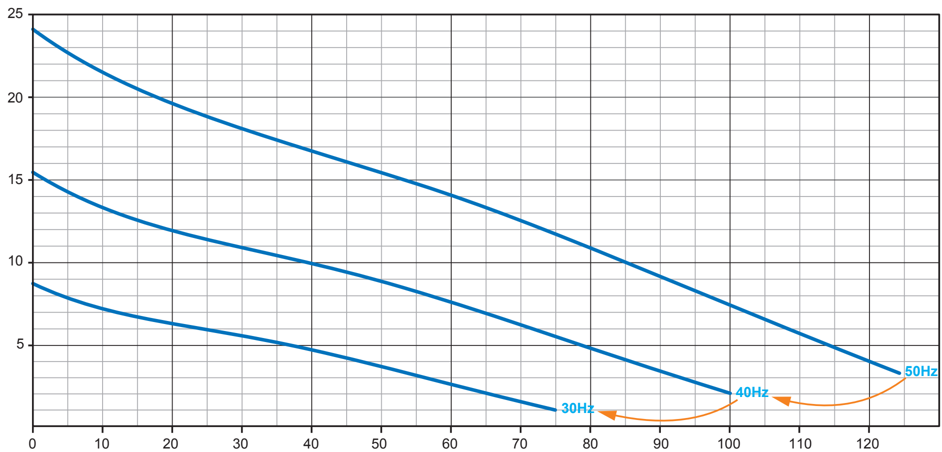
- Q = 100 l/s
- H = 10 m
- P2 = 15 kW
- **η** = 100 ×10/(1.02x15) = 65.36 %

At 40 Hz:

- Q = 100 × (40/50) = 80 l/s
- H = 10 × (40/50)2 = 6.4 m
- P2 = 15 × (40/50)3 = 7.68 kW
- **η** = 80 × 6.4 / (1.02 × 7.68) = 65.36%

At 30 Hz:

- Q = 100 × (30/50) = 60 l/s
- H = 10 × (30/50)2 = 3.6 m
- P2 = 15 × (30/50)3 = 3.24 kW
- **η** = 60 × 3.6 / (1.02 × 3.24) = 65.36%



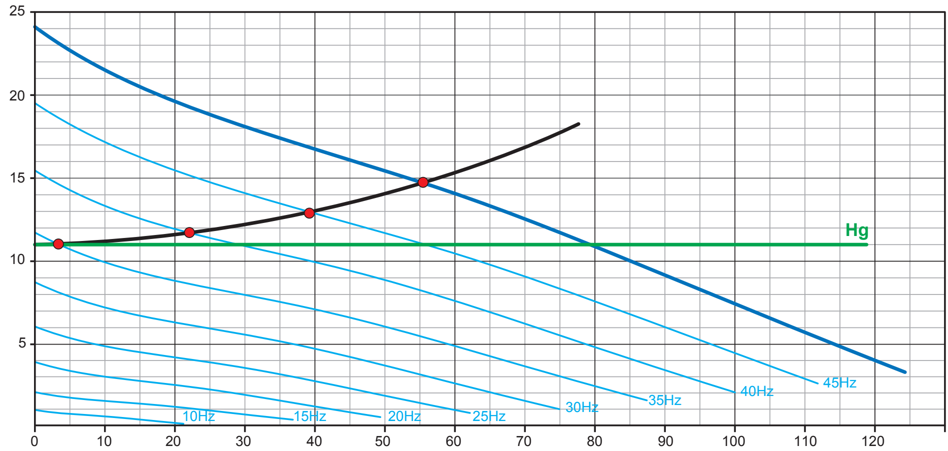
5.2 Limits

Frequency

For centrifugal pumps, the frequency range within which the pump can operate is limited above by the pump's frequency rating (50 or 60 Hz). There is no lower limit for all pumps, but each pump may have its own limit, depending on factors including:

- collapse of the characteristic curve
- inefficiency of the cooling system on dry pumps

Manufacturers even allow selection of frequencies below 10 Hz. The principle limiting factor is not the pump itself, but the hydraulic circuit. Reducing the frequency may lower the characteristic curve completely below the geodetic head and the flow rate would thus be zero.



In the example, the frequency range is limited to 35 Hz, since the flow rate is zero below that value.

Motor power

In general, operation with an inverter heats the motor more for a given power draw. It is thus necessary to evaluate the duty range and make sure that at the maximum frequency, the P2 required is lower than the rated P2. The power margin must be greater the less efficient the motor itself (usually 5-10% is sufficient).

Motors in explosion proof construction (ATEX)

As said above, for a given load, a motor will heat up more when controlled by an inverter.
This may result in a motor in temperature class T4 being derated to class T3 when inverter controlled. Detailed information on this is available in the user and maintenance manual.

5.3 Applications

Variable frequency drives are used on submersible sewer pumps in a variety of applications and requirements, including regulating the flow rate to satisfy particular process parameters (typical of sludge recirculation), limiting hydraulic load peaks and reducing pumping costs. The variable frequency drive also acts as a soft starter and includes amperometric motor protection.

Rev.2

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