An influential study of differential parameters to elect the special pumping stations and suitable electric pumps

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Abstract

The pumping station is a collection of pumps, driving forces and auxiliary equipment e.g., collector system, power supply system, and control and protection systems. Small pumping stations are usually designed in the simplest possible way for the ease of operation of auxiliary equipment. However, as the capacity of the pumping station increases, the technical complexity and design of peripheral equipment increases, which requires its design according to the conditions, type of work, and location of the project. The choice of the type of station building, and the type and capacity of the main and reserve pumps, by the special conditions of each project, are contingent upon the nature of the plan. This study evaluates the basics of designing pumping stations, taking into account the above-mentioned issues, focusing on the system of pumping and transferring water from Dasht Zozen to the central site of the water supply facilities of Sangan Industries.

Keywords: Pumping station, water transfer system, pump capacity

1. Introduction

Sangan Khaf iron ore mines are located in the eastern part of Razavi Khorasan province, 280 km southeast of Mashhad, 30 km southeast of Khaf city, 18 km northeast of Sangan city and 30 km away from the border with Afghanistan. Sangan iron ore complex is the most important and biggest industry located in Khaf city. This steel production company plays an important role in sustainable employment and infrastructure development of the deprived border area as well as providing security. This industry helps the province of Razavi Khorasan to prosper by using its large volume of mineral reserves, which is necessary for the production of concentrate and iron pellets. Moreover, since the industry is in developmental stage, it is providing direct and indirect employment opportunities to the local people, thus boosting the eastern part of the country economically.

The provision of water as a required investment input is also a planning vision for accelerating and launching the complex. Moreover, it is an important factor in the national interest and security, by ensuring employment stability in the eastern border area of Razavi Khorasan Province, all of which requires management of the water. Supply industry People and experts take seriously the increase in water supply methods and industry water consumption.

It is necessary to provide water as a required investment input as well as a planning vision to accelerate the process of launching the complex. The project is vital for the national interest, security stability and employment in the eastern border region of Razavi Khorasan Province. The way water is supplied and consumed is a source of concern to people and experts. Thus, it is necessary to take wise actions in the management of the water.

One of the water supply plans for Sangan iron ore industries is the use of saline water sources in Zozen plain. For this purpose, a water transmission system with a capacity of 6 million cubic meters per year has been designed, including water transmission lines, pumping stations, equipment and facilities, storage and balancing tanks, construction and

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auxiliary units, technical buildings and required landscaping.

In this article, using the outputs of the above-mentioned plan as a concrete example, the key points in the mechanical design of pumping stations and the selection of their main equipment have been briefly presented.

2. Literature review:

General, it is most important from aspect of practical and economical the analyzing of flows. There are many studies in this subject. Driels (1975), proposed a new method in which the pressure was reduced to a constant value by using a pressure relief valve and the minimum pressure remains in all points. Shimada and Okushima. (1984), investigated the effects of closing valve on creating RIP by characteristic lines. Chaudhry (1979) presented two difference diagram in frictionless and friction conditions for Lagrange expansion to analyses of the compressible and non-compressible flow fluid as well as the concept of velocity potential. Ghidaoui and Kolyshkin (2001), presented a step-by-step computational method to determine the changes in water turbine velocity that occurs due to changes in load. They considered the RI pressures, changing in turbine efficiency due to change in valve opening rate as well as uniform and non-uniform valve movements. Bergant et al. (2001), incorporated two unsteady friction models proposed by Zielke (1968) and Brunone et al (1991) into MOC water hammer analysis.

Ghidaoui et al. (2002), implemented and analyzed the two layer and the five-layer eddy viscosity models of water hammer. A dimensionless parameter i.e., the ratio of the time scale of the radial diffusion of shear to the time scale of wave propagation has been developed for assessing the accuracy of the assumption of flow axisymmetric in both the models of water hammer.

Zhao and Ghidaoui (2003), have solved a quasi-two dimensional model for turbulent flow in water hammer. They have considered turbulent shear stress as resistance instead of friction factor. Zhao and Ghidaoui (2004) Applied first - and second-order Godunov-type schemes for water hammer problems. Numerical tests showed that the first -order Godunov gives the same results to the MOC with space-line interpolation. Mimi and Kumar (2006), showed that at the performance of numerical methods, friction errors grow in unsteady flows, which are estimated in small pipeline networks for fixed coordinate plates, which is so the characteristic lines without interpolation.

Tijsseling and Bergant (2007), proposed a method based on the MOC, but a numerical grid is not required. The water hammer equations without friction have been solved exactly for the time -dependent boundary and constant (steady state) initial conditions with this method. Their method was the simplicity of the algorithm (recursion) and the fast and accurate (exact) calculation of transient events but calculation time strongly increased the events of longer duration. Kwon and Lee (2008), simulated transient flow in a pipe involving backflow preventers using both experimental and three different numerical models of the method of characteristics model (MOC), the asymmetrical model and the implicit scheme model. The results of different computer models agree well with the experimental data.

Hou. et al. (2012), simulated water hammer with the corrective smoothed particle method (CSPM). The CSPM results are in good agreement with conventional MOC solutions. This paper aims at the investigation of four explicit finite difference solutions of water hammer and their comparison with the largely established solutions of MOC and Godunov. (2) (PDF) Water hammer simulation by explicit central finite difference methods in staggered grids. Available from: It is necessary to have access to the distribution of head and flow rate in different operating conditions to design and operate any pipeline. For this reason, many of researchers have simulated transient flows in water pipelines by using variety of methods. Among the existing methods, numerical methods have acceptable accuracy compared to other methods. In the numerical methods, the two methods of characteristic lines and finite difference have many applications in solving related equations. Therefore, the study of these two methods in analyzing the RIP is importance that has been tried to be investigate in this study.

According to the studies the water velocity in penstock pipes is over 10 m/s. then the line pressure due to high velocity causes problems into this pipes. For controlling of the unsteady flow it can be used the finite element and characteristic lines methods. In this study we investigated a simple method for prediction amount of the flow before arriving to the hydropower plants by characteristic lines method. Aghamajidi etal (2021) studied the effect of the effect of unsteady flow in power plant hydro power. In this research they concluded that not to use certain time steps and try as much as possible avoid interpolation by selecting the appropriate time step. The results of examining the amount of changes in coefficient of friction in both methods show that it is not correct to take its value constant (proportional to the value obtained in stable conditions) and coefficient of friction should be calculated in proportion to changes in velocity at different times and used in the governing equation.

3. Design of pumping stations:

A pumping station is a collection of pumps, drivir forces and peripheral equipment e.g., collector system power supply systems, control and protection system Small pumping stations are usually designed in th simplest possible way for the ease of operation c peripheral equipment. However, as the capacity of th pumping station increases, so does the technic complexity and design of peripheral equipment, whic requires its own design according to the conditions, ty of work, and location of the project [1].

3.1. Location of pumping stations

The geographical location of pumping stations strongly influences the entire station design process. To choose the geographical location of the station, there are things such as proximity to the water source, the route of the water transmission line, the resistance of the construction site, service road, energy transmission lines, land ownership, natural and man-made structures, flood risk and other risks that disrupt services should be considered (Publication 470 of the Program and Budget Organization) [1,2].

3.2. Type of pumping stations

Based on the installation method, pump stations can be divided into the following types [3,4]:

3.2.1. Pumping stations with horizontal pumps

Horizontal pumps need a relatively large space for their engine. Thus, they are used when there is not much space limitation in the station. An example of a horizontal pumping station is shown in Figure 1.

Figure 1. Pumping stations with horizontal pumps.

Figure 2. the other view for special Pumping stations with horizontal pumps.

- **The advantages of horizontal pumping stations are as follows:**

- Both the pump and the electric motor are easy to repair,
- It is easy to separate the pump and the electric motor, as there is no need for special arrangements, and
- There is no limitation in the selection of pumping capacity due to the wide range of horizontal pump products from the point of view of transfer flow and pumping height.

The disadvantages of horizontal pumping stations are as follows:

- More space is needed in order to install the pump and electric motor and the suction pipeline,
- The pumping hall must be ventilated due to the thermal load produced by electric motors, and
- There is more noise and vibration in the environment of the pumping station hall.

3.2.2. Pumping stations with vertical pumps [4]:

The pumps used in these stations are shaft and sheath type or submersible (floating).

A- Shaft-sleeve pumps

In this case, the impeller and a part of the pump shell may be placed in the water, but the driving engine is installed above water level. A diesel or electric motor may be used as the driving engine. The whole shell may be placed outside the water with the suction opening of the pump being connected to the suction tank via a pipe.

Shaft-sleeve pumps can be divided into several categories:

- Deep well shaft and casing pumps whose shaft and casing length may reach more than one hundred meters.
- Shaft and sheath pumps with short length for installation in shallow wells and urban water tanks
- Two-shell (barrel) shaft and casing pumps, in which a normal vertical pump is placed inside a cylindrical shell, and in this way, there are better suction conditions in terms of water level control, as well as the calmness of the input flow to the pump wheel.

Figure 2 shows an example of a vertical pumping station using shaft-sleeve pumps.

Figure 2. A vertical pumping station using shaft and sheath pumps.

The advantages of vertical pumping stations with shaft-sleeve pumps are as follows:

- Reducing the space required to install the pump and electric motor,
- Removal of suction pipeline equipment,
- Availability of the electric motor for repairs,
- The ability to separate the pump and the electric motor without the need for special arrangements,

The disadvantages of vertical pumping stations using shaft-sleeve pumps are as follows:

- The need to ventilate the pumping hall due to the thermal load produced by electric motors,
- Presence of noise and vibration in the pumping room environment,
- Selection of pumping capacity due to the limited range of production of shaft-sleeve pumps, and
- Old technology and problems of coupling the pump and electric motor through the intermediate shaft, especially for long distances.

B- Submersible pumps

Submersible pumps, used for pumping fluid from a great depth, are becoming increasingly popular. Submersible pumps allow the whole body of the pump, along with the motor, to be submerged in water. Mechanical seals are used to prevent water from entering the engine, which is located below the pump. The problem with this system is that if the engine needs repair, the entire assembly must be removed from the water. The electric motor is made with a diameter corresponding to the pipe of the well wall and is cooled by water.

Figure 3 shows an example of a vertical pumping station using submersible pumps.

Figure 3. Vertical pumping station using floating pumps.

The advantages of vertical pumping stations with submersible pumps are as follows:

- Reducing the space required to install the pump and electric motor,
- Removal of suction pipeline equipment,
- No need for ventilation due to the cooling of electric motors through passing water,

- Noticeable reduction of noise and vibration in the pumping hall environment,

- Removing the intermediate shaft between the pump and the electric motor and eliminating the problems caused by it,

- The widespread use of floating pumps in the country, especially in the agricultural sector, and the familiarity of operators and repairmen with their operation and repair methods, and

- Abundance of spare parts due to the use of general products of pump manufacturers (routine products).

The disadvantages of vertical pumping stations using submersible pumps are as follows:

- A limitation in the selection of pumping capacity due to the limited range of production of floating pumps,

- Unavailability of the electric motor for repairs, and

- The inability to separate the pump and the electric motor without the need for special arrangements.

3.3. Electropumps

The working period for electric pumps is usually 10 to 15 years. The pump then becomes less efficient due to the high consumption rate, which it necessary to replace the pump and select a new one [5,6].

2.3.1. Classification of pumps

Pumps are classified based on various factors such as the type of consumption, the internal structure, and energy transfer method. The most common way of dividing pumps is based on how kinetic energy is imparted to fluid. From this point of view, pumps are divided into two main categories:

- Pumps that use increased flow velocity to impart kinetic energy to the fluid (Dynamic Pumps).

- Pump that moves a fluid by repeatedly enclosing a fixed volume, with the aid of seals or valves (Displacement Pumps).

Given the nature and capacity of water transmission lines, dynamic pumps are used in water pumping stations. Turbo Pumps or Impeller Pumps, which are known as centrifugal pumps, form a wide subset of dynamic pumps. They are widely used for pumping liquids, especially water. The most common method of classifying pumps from the design point of view is based on the direction of fluid movement in the pump wheel. From this point of view, pumps are divided into three main categories.

- Centrifugal Pumps
- Axial Flow Pumps
- Mixed Flow Pumps

Centrifugal pumps are used to create high pressure for low viscosity fluids, axial flow pumps are employed for large volume flows at relatively low delivery heads, and mixed flow pumps are used for pumping a medium or high flow rate at a medium delivery head.

3.3.2. The main characteristics of electric pumps

A- Volumetric flow Q

The flow rate of a pump is the effective amount of fluid volume that leaves the pump outlet in a unit of time. The pump discharge changes with the production height. The flow on which the pump is selected is called the nominal flow.

B- Total height H

The total height of a pump is the amount of useful power that is transferred by the pump to the unit weight of the fluid. The height based on which the pump is selected is called the nominal height.

C- Consumable power and useful power P

Power consumption is the power that the motor puts on the pump axis. The useful power is the amount of power given to the fluid by the pump, which is equal to the product of the useful height produced by the weight of the fluid transported by the pump; The difference between the consumed power and the useful power is due to various losses e.g., hydraulic and mechanical losses inside the pump.

D- Total pump efficiency η

The total efficiency of the pump is the ratio between the useful power and the consumed power of the pump. The efficiency of centrifugal pumps is contingent upon the size of the pump, the rotational speed of the pump and the specific speed. By increasing the rotational speed and size of the pump, its efficiency increases due to the Reynolds number and the effect of increasing the speed on the production height and the quantity of hydraulic losses of the pump. By increasing the rotational speed of the pump, the amount of production height increases more than the quantity of hydraulic losses, as a result of which the efficiency of the pump increases.

E- N pump round

While some centrifugal pumps work with variable speed motors, they are often used with constant speed motors due to economic concerns and points related to proper operation. The use of variable speed pumps is uncommon in terms of design size and pumps used, and cost. Usually, the speed of rotation is set to the standard speed of the motor, such as 980 or 1450 or 2900 revolutions per minute (AC at 50 Hz). Choosing high revs may be appropriate in terms of engine economy and efficiency, but can lead to problems such as cavitation and rapid consumption of moving parts. In any case, the manufacturer will provide the appropriate rounds for each pump based on the necessary calculations for high efficiency and necessary NPSH, taking into account flow and height.

F- NPSH net positive suction height

Vacuum or cavitation phenomena affect pump performance. Whenever a fluid flow passes through an impeller, when the flow pressure is lower than the vaporization pressure of the fluid at the appropriate temperature, bubbles form and move with the fluid to another point where the pressure is higher. If the liquid pressure is high enough at the new place, then the bubbles will be distilled outward there; as a result, the liquid particles will hit the surroundings, including the blades, at extremely high speeds. This phenomenon reduces the life span of the blades and creates noise and vibration during operation, hence reducing the performance of the pump.

In centrifugal pumps, when the liquid enters the wheel the pressure drops locally and reaches its minimum at a point close to the wheel inlet due to the increase in speed. If at this point (minimum pressure point), the liquid pressure is higher than the evaporation pressure of the liquid passing through the pump, the liquid will always remain in one phase during its movement inside the wheel. Hence, cavitation phenomenon will not occur. In order to check the condition of not causing cavitation in pumps, two values NPSHreq and NPSHavial are defined.

NPSHavial: is the fluid pressure in the suction opening.

NPSHreq: the minimum required fluid pressure in the suction opening to prevent cavitation.

The value of NPSHreq is provided by the manufacturer and often includes a 0.5 m margin of confidence. In order to create conditions to ensure that cavitation does not occur in the pump, it is necessary to always have the following relationship.

NPSHavial>NPSHreq

We always try to make NPSHavial about 2 meters and at least 0.6 meters more than NPSHreq. The following methods can be used to reduce NPSHreq:

It is recommended to make NPSHavial about 2 meters and at least 0.6 meters more than NPSHreq. The following methods can be used to reduce NPSHreq:

- Choosing a pump with a lower rotational speed,
- Splitting the flow between several pumps or using a pump with two inlets,

The following methods are also suggested to raise NPSHavial:

- Choosing the right height for the suction tank,
- Selection of low fluid speed at the pump inlet, and
- Reducing losses in the suction pipe (for this purpose, the flow control valve should never be placed on the suction pipe. Also, the diameter of the suction pipe should be larger than that of the thrust pipe if necessary).

3.3.3. Characteristic curve of turbo pumps

The working conditions of the pump are determined by the following variables and the relationships between them.

A- Hydraulic variables including volume flow rate Q, total height H and working conditions in terms of NPSH cavitation, and

B- Mechanical variables including rotational speed N and power consumption P.

In turbo pumps, there is only one hydraulic independent variable and one mechanical independent variable, with the rest of the specifications being dependent on them. In practice, one rotational speed variable N and another volumetric flow rate Q are selected and the rest of the parameters are drawn accordingly. In this case:

H = f1(Q, N)
P = f2(Q, N)
Z = f3(Q, N)
NPSH = f4(Q,N)
Each of the above relationships defines a surface in space, after drawing in the 3D coordinate system.
The above curve is not easy to use. Thus, for a certain speed N, the characteristics of a pump can be determined by the common section of the characteristic surfaces with a constant surface N = in this case. The following relationships will prevail at a constant rotational speed.
H = f1(Q)
P = f2(Q)
Z = f3(Q)
NPSH = f4(Q)
The above equations, which can be drawn as curves on a page, are called characteristic curves of turbo pumps, which are provided by pump manufacturers.
Figure 4 shows a sample of the characteristic curve of centrifugal pumps.

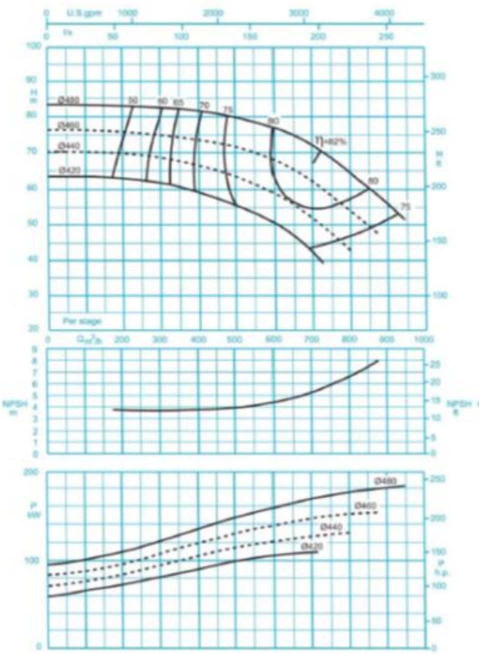

Figure 4. Sample characteristic curve of centrifugal pumps.

3.3.4. Parallel pumps

Pumps can be connected in series and parallel. When they are connected in series, they all pump the same flow, but their feed is summed up. When the pumps are connected in parallel, the pressure is the same for all, and the feeds are added up, but the total feed is not equal to the product of the feed of one pump by their number. In other words, the total flow is always lower than the specified value. Therefore, it is necessary to plot the system and pump head curves and determine the total flow of the pumping system and each of the pumps.
The following points should be considered when connecting several pumps in parallel:
a) When parallel pumps are turned off and on, if different pumps are used, there will be a possibility of water returning from one pump to another.
b) Since the characteristic curve of the system has an upward shape with increasing flow, if two identical pumps are connected in parallel, for example, the total flow does not double. This issue should be taken into account when choosing pumps.
c) When the pumps are connected in parallel, the dynamic resistance of the circuit should be kept as low as possible, because the greater the slope of the circuit characteristic curve, the lower the production flow rate of the group of pumps, and there may even be no intersection between the H-Q characteristic curve of the pump and the characteristic curve of the circuit.
d) Since the production flow of each pump in parallel operation is lower than in negative operation, when one pump is stopped, the production flow of the other pumps increases. This should be considered when selecting a drive motor and NPSHR [7].

3.3.5. Selection of capacity and type of pumps

The pump selection process includes finding the most suitable pump with the highest efficiency that can provide the desired flow height. Keeping the cost factor in mind, it is recommended to buy the selected pump from a manufacturer which guarantees the proper functioning of the pump, and which can be accessed quickly if repairs are needed. In other words, domestic manufacturers are more reliable than foreign manufacturers. Other factors should be taken into consideration to choose the pumps of a pumping station. Using similar pumps in the station reduces costs. At a glance, horizontal pumps are lighter in terms of weight and cheaper than vertical types. So, if there is no shortage of space in the station, it is preferable to use horizontal pumps.

The process of choosing the right pump for a pumping station is complex. An experienced design engineer chooses the best design from the possible options considering various parameters. Thus, various points should be specified:

- Water supply source (physical and chemical conditions of water),
- Design of flow rate (maximum required flow rate), and
- Working point conditions (pumping height, minimum and maximum capacity, efficiency and NPSHR).

After estimating the above points, the following should be considered:

- Installation position of pumps,
- Available driving machine (electric or diesel engine, constant or variable speed), and
- Location of the pumping station, available space and limitations,

Before choosing the type and size of the pump, the design flow rate must be known. Some empirical recommendations in the field of pump selection are as follows:

- Try to provide the maximum flow rate with at least two pumps.
- Try to ensure the flow rate by at least one pump.
- To reduce the need for spare parts, select pumps of the same size.
- Try to select the pumps around the point of best efficiency in the most possible mode of operation.
- The number of standby pumps should be determined according to the sensitivity of the plan and the possibility of maintenance periods.

In summary, the total cost as well as the availability and power consumption of the chosen pump are factors in choosing the type and size of the pump, which may increase the number of pumps required. After the initial selection of the pump has been determined, the operating conditions must be fully controlled.

3.3.6. The number of working and reserved pumps at each station

The number of pumps (electric motors) in each pumping station is one of the effective factors in choosing the type of pump. In addition, by installing the necessary pumps in the pumping station, it is rare to expect full performance from that station. That is why it is necessary to provide additional standby pumps [7].

Normally the flexibility of operation increases in pumping stations by dividing the required capacity between a larger number of pumps. Yet, increasing the number of pumps increases the costs of plumbing, faucets, and other mechanical and electrical equipment, so do the required space and construction costs. Therefore, to determine the number of pumps, the effect of various factors should be taken into account, including the working conditions of the pumps in terms of flow rate and pumping height, the space required for each pump and its effect on the dimensions of the building and substructure, the purchase price of each pump and accessories, the possibility of repair and service. Normally, the number of pumps in pumping stations is as follows:

- Small stations (flow rate less than 160 m 3 /hr) one pump with one reserve pumps,
- Medium stations (160-450 m 3 /hr) two pumps with a number of reserve pumps,
- Large stations (flow rate more than 450 m 3 /hr) five pumps with a number of reserve pumps.

It is also vital to consider the assortment of products of different companies for feeding and dividing the total power of the pumping station in such a way that the supplied power of each pump falls within this range.

3.3.7. Selection of the type of pump

The first centrifugal pumps found practical application in the late 17th and early 18th centuries. In the middle of the 19th century, the main disadvantage of piston pumps i.e., low flow made centrifugal pumps more popular and helped them find a wider place in the industry. In centrifugal pumps, the liquid enters the center of the pump and the base of the blades, and under the action of the centrifugal force caused by the rapid rotation of the pump, it acquires a large kinetic energy and is thrown out, filling the shells with liquid and the kinetic energy in the output part of the pump is necessarily converted into pressure energy. The benefits of these pumps include:

- Centrifugal pumps have a simple structure and are made of various materials.
- Because the pump operates at a high speed, it can be directly connected to the electric motor. As the speed increases for a given function, the dimensions of the pump become smaller.
- Its flow rate is uniform.
- Its repair cost is lower than that of other pumps.
- In the event of a power cut, it can continue to circulate for a period of time without damaging the pump.
- They work well for transferring fluids with suspended substances.
- Compared to other pumps with similar capacity, they have smaller dimensions.

3.3.8. Determining the operating point of the pump

The pumps are selected so that the intersection of the system curve and the parallel pump curves in all situations where pump performance varies from minimum to maximum, does not result in the pumps being in low efficiency conditions or in the range above the BEP. dot. By standards, this range varies from 60 to 125% of the optimal flow rate. In addition, the operating range of the pump must be in optimal conditions in terms of efficiency and NPSH.

The maximum and minimum static head should be checked and the changes in the flow rate of these heads should be controlled so that it does not fall outside the permissible range. The highest static head is obtained when the water in the suction tank is at the lowest level and in the thrust tank at the highest level. The lowest static head is also achieved when the water in the suction and thrust tank is at the highest level. Figure 5 shows an example of how the system curve and the pump curve intersect.

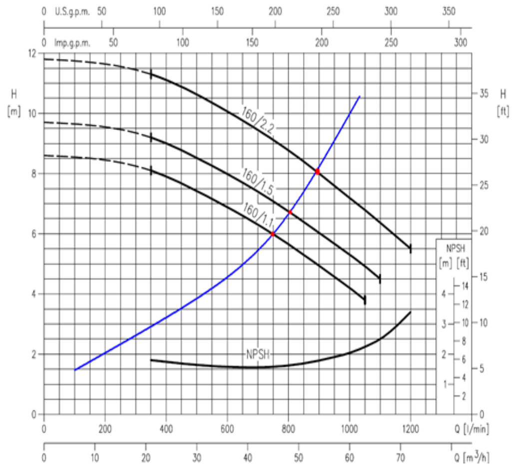

Figure 5. Head-discharge curve of the system and pump and determining the working point of the pumping system.

4 Selecting electropumps and determining their number and capacity in the Sangan iron ore mine water transmission system

A case study and design has been carried out regarding the determination of the type of pumping stations, the capacity and number of electropumps, taking into account the above-mentioned items, which is presented below.

4.1. Flow rate design

In this plan, the average working hours of pumping is 20 hours per day, and with this consideration, the transfer capacity of 6 million cubic meters per year, the designed flow rate is 230 liters per second.

4.2. Hydraulic calculations

Considering the importance of value engineering and reducing the investment and current costs of the project, preliminary hydraulic calculations were performed for three hydraulic options and finally, based on the investigations, the best option was selected.

In the proposed option, water is transported by three pumping stations and a fiberglass pipeline with a nominal diameter of 500 mm. In Table 1, the hydraulic specifications of the electric pumps in this option and in Figure 6, the hydraulic profile of the mentioned option modeled by WaterGEMS software can be seen.

Table 1. the description of water pump in the project.

umping station	acity(Kw)	ght(m)	(lit/s)
#1	620	206	30
#2	620	206	30
#3	620	206	30

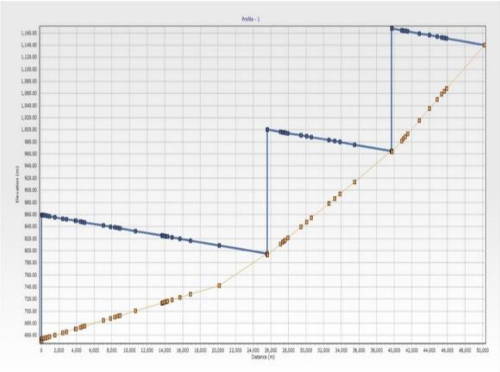

Figure 6. Hydraulic profile of the route with 3 pumping stations (diameter 500 mm).

4.3. Determining the capacity of the pumps and the number of working and reserved ones

4.3.1. The use of horizontal centrifugal pumps[5]

In this scheme, given the production range of domestic manufacturers, as well as the total delivery flow (230 liters/second), equal pump levels are considered. Hence, 4 main pumps are sufficient for each pump station. Thus, each pump has a nominal capacity of approximately 57.5 liters per second at the operating point. In addition, 1 backup pump is considered for each pumping station, which corresponds to about 25% of the total capacity. it is not recommended to reduce the number of working and reserve pumps, even with the production of horizontal pumps with higher capacity.

According to hydraulic calculations, the pumping height of the pumping station is about 206 meters of water column. Depending on the number of pumps in the pumping station, each pump has a capacity of about 57.5 liters per second at the operating point. As to the flow and head capacity, referring to Pumpiran's catalog as the largest domestic pump manufacturer, the following pumps can be selected.

High pressure centrifugal pump WKL/125/03/DD310/1450rpm

Figure 7 shows the characteristic curve of the mentioned pumps along with the working point.

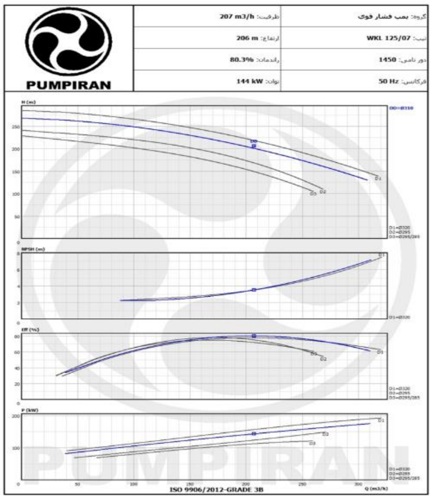

Figure 7. Characteristic curve of horizontal high pressure centrifugal pump (WKL/125/03/DD310/1450rpm)

4.3.2 Using vertical centrifugal pumps (immersed)

If vertical centrifugal pumps are used in the present design, 4 main pumps are sufficient for each pumping station. Thus, the nominal capacity of each pump at the working point will be about 57.5 liters per second. Meanwhile, 1 reserve pump, equivalent to about 25% of the total capacity, is needed as a ready-to-use pump in each pumping station. [7]

As shown by hydraulic calculations, the pumping height of the pumping station is about 206 meters of water column. Depending on the number of pumps in the pumping station, each pump has a capacity of about 57.5 liters per second at the operating point. As to flow and head capacity, referring to Pumpiran's catalog, as the largest domestic pump manufacturer, the following pumps can be selected.

Deep well floating centrifugal pump BRTS/435/07/DD172-166/2900rpm

Figure 8 shows the characteristic curve of the mentioned pumps along with the working point.

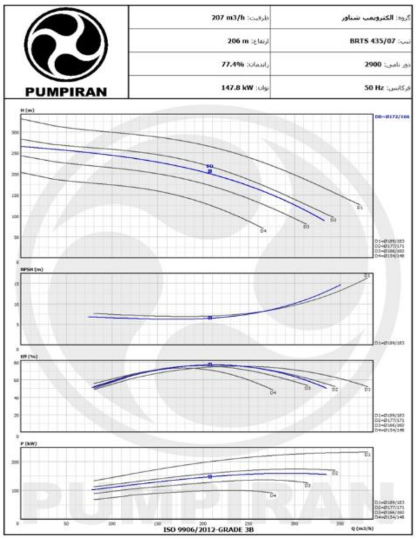

Figure 8. Characteristic curve of deep well submersible centrifugal pump (BRTS/435/07/DD172-166/2900rpm).

4.4. Cost estimation

Considering that the contribution of the difference in the cost of the pump station structure is negligible compared to the difference in the cost of the equipment provided, the number and capacity of the pumps are the same in both cases where horizontal or vertical centrifugal pumps are used, so in this section, only the cost of supplying the electric pump is given for comparison. the cost is provided irrespective of the cost of the piping system, the construction cost of the well required to install the immersed pump, the cost of transportation, installation, etc.

Table 2 comparing the cost of supplying horizontal and vertical electric pumps.

Table 2. The cost of supplying horizontal and vertical electric pumps.

scription	ıp price	ctric motor	number stations	ıl sum hree 3 tions
g pressure rizontal) ıtrifugal ›umps	000‹000	)000‹000‹00	15	35
›ep well ımersed ertical)	000‹000	)0‹000‹000	15	35

- The prices are extracted from the Pump Iran agency website, related to February 1400.
- The offered prices are related to routine production products and the costs related to design modification or consumables for transporting salt and brackish water are not included in them.
- All are net prices and the costs related to transportation and installation and other costs such as taxes and legal deductions are not included in them.

Considering the difference in efficiency of about 3% of the selected horizontal centrifugal pumps compared to the proposed immersed pumps, the difference in annual electricity consumption costs of both options is presented in Table 3.

As can be seen, in the purchase of electric pumps, horizontal pumps are approximately 2000 million Rials cheaper than vertical pumps, which is not considered a significant difference at this level, but in the electricity consumption sector, the difference between the two is about 88 billion Rial compared to the cost of supplying pumping station equipment, which it is significant.

5. Conclusions

Based on the information presented in the previous sections, considering that the cost of providing equipment in the two options of the horizontal and vertical pumping stations is almost the same, but since the efficiency of the horizontal high-pressure pump is higher than that of the submerged pump at this point, the horizontal centrifugal pump is recommended for this plan, as the efficiency varies during operation, resulting in significant energy savings.

Another noteworthy point is that if horizontal pumps are used, the required speed of the electric motor will be 1450 rpm, while the required speed for vertical submersible pumps is around 2900 rpm. Reducing the speed of electric pumps will slows down the depreciation process and increases the lifespan of the equipment. Thus, if horizontal pumps are used, the useful life of the pump increases, while the depreciation of the facilities will be reduced.

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