

Theoretical Study to Choose The Appropriate Pumps To Solve The Problem of Low Water Levels of The Iraqi Rivers With The Design of A Floating Pumping Station

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Abstract: A study was prepared to select the appropriate pumps for pump stations in order to predict the decrease in the level of Iraq's rivers in general and problems in the pumping stations as a result of this decrease in addition the study was prepared to address the problems in the water pumping projects (pumping stations) in 2019 at the University of Baghdad, the study can be applied for all central and subsidiary water pumping projects spread throughout the provinces, note that the study includes the (introduction of basic data such as the rise of the river level, dimension the location of the pump for the river, the required height for pumping water and the amount of water required to pump (m³/h), the diameter of the pipes to be used, connecting accessories, the number of entrances and exits of the system, check valves etc..). The study also includes the design of a floating pumping station to address the problem and the study also aims to reduce the financial cost in terms of the use of ideal pump set (motor + pump) for river level (upper and lower) and thus reduce the engine horsepower, i.e. reducing the power of the engine required for operation, in addition to reducing the cost to buy expensive pumps with high horsepower, reducing the sizes and types of pipes used, as well as reducing the connecting accessories, and thus we have solved technical and economic problems at the same time.

Keywords: centrifugal pumps; pumping projects; hydropower; brake horsepower.

I. Introduction

For a long time, Iraqi territory has been negatively affected by the decrease in the water received through the Tigris and Euphrates rivers, which, according to experts, made it the most serious water crisis in Iraq's history. This crisis caused a great loss of agricultural land estimated at 40 percent of its land, the construction of dams and giant water reservoirs in neighboring countries that affected a lot on the water of the rivers sloping towards Iraq so that the amount of access to it became not enough to meet the needs of agriculture, industry, Energy and livestock farming, but it has come to drinking water and humanitarian needs. The function of the pump in any pumping system or station is to generate enough pressure to overcome the operational pressure of the system to be able to transport water at a certain discharge rate. The operational pressure of the system is a function of discharge through the system and the arrangement of its parts such as (lengths and sizes of pipes, connecting attachments for pipes, change in water height and pressures on fluid surfaces (suction and delivery)) and others. To calculate the required discharge in the pumping system, it requires us to calculate the operational pressures in the system to select the appropriate pump for this purpose. To choose a suction pump with a certain capacity (appropriate pressure) requires knowing the load required to feed the area to be supplied with water and therefore the amount of water required on the basis of which the size of the pump and the capacity required for it are determined. But sometimes the level of the river decreases and therefore the pump used is useless to provide the required water and therefore requires treatment using additional submersible pumps to draw water and provide the necessary pressure to draw the required water and this method is an alternative to lengthening the suction that are too many disadvantages due to the lack of pressure to draw water, which results in intermittent water withdrawal and sometimes the inability to draw completely. In addition, the use of submersible pumps is an impractical solution because it is very expensive and therefore will cost the institution additional high amounts in addition to the problems of equipping it with electric power and mechanical problems related to the connection of the parts of the submersible pumps with the main system,[1].

goal of the study: Will be studied how to choose the appropriate pump that provides the necessary pressure to draw the required water in case the river level is normal or low to the lowest expected level by studying the determinants that directly affect the work of the pump. In addition, the design of a floating pumping station is an additional solution.

II. MATERIAL AND METHODS

A. Mathematical model: the mathematical model is represented by the assumption that the water pumping process will be carried out from the water source, represented by the river or any water reservoir which is at a variable pressure (depends on the height of the water at the source) which represents the source of the water suction, to the receiver of the water Withdrawn from the water assembly area, which is at a constant pressure and the water level in the stored area of the water withdrawn. Thus, the pressure required from the pump is the pressure difference between the source of the suction (river or reservoir) and the water collection tank, as shown in the chart Fig. 1. Water is withdrawn from the river or from the suction tank to the assembly tank (delivery point) and this method is used in all stations and projects of filtering and sterilization and then the water is transferred to the system scattered in the area to be consumed by the citizens. The water level in the river varies, but the level of the assembly tank is constant, where the water is discharged from a point is higher above the tank. And the required of the pump, delivery a certain amount of Q (m^3/h) into the assembly tank. The operational pressures of the pumping system are calculated in international measurement units (SI) and meters (relative to the water(m) for ease and for the coordination of units as well as the rest of the pressures used will be handled in meters. The conversion of units from (kPa) to (m) is carried out through the following relationship,[2]:

$$1 \text{ kPa} = 0.1020 \text{ m (water mete)} \dots\dots\dots(1)$$

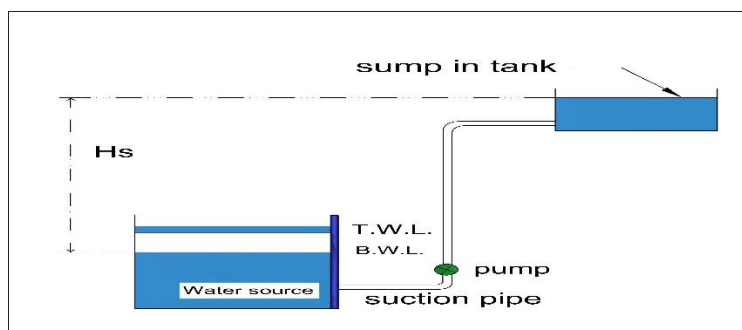


Fig. 1. The Sequence of the Pumping Process from Source to Receiver.

In order to select the appropriate pump, the total capacity value required for operation must be calculated through the following equation, [2,3]:

$$P = \frac{Q \times H \times g \times \rho}{\zeta} \dots\dots\dots (2)$$

Where : Q = Discharge ($m^3/hr.$) g = Ground acceleration ρ = water density. ζ = pump efficiency

H = Head,(TDH) Total dynamic head, the total pressure of the system which consist of a pipe line system that connects the source of the drawn water to the assembly tank and its unit is (m). The (TDH) of the system can be calculated by the following equation,[3] :

$$H = H_s + H_d + (H_{RT} - H_{RES}) \dots\dots\dots (3)$$

Where: H_{RT} : Pressure above the surface of the assembly tank water and is equal to the atmospheric pressure of the open tanks.

H_{RES} : Pressure above the level of the river surface or tanks of the source of water withdrawal river and be equal to the atmospheric pressure of open tanks.

Therefore, if the source of water withdrawal from the river (open reservoir) and the water collection reservoir are open, the difference between the two water levels is relatively close, the output of the amount $(H_{RT} - H_{RES}) \sim (0)$ so that law 3 of open reservoirs can be reformulated to the converging water levels in the cloud and assembly reservoirs in the following manner,[4]:

$$H = H_s + H_d \dots\dots\dots (4)$$

In the case of water levels between the source of the river and the water collection reservoir, the amount of atmospheric pressure is uneven for the two levels of water (source of clouds and assembly) and therefore must be taken into account, i.e. ($H_{RT} - H_{RES} \neq (0)$) and therefore equation (3) must be used.

H_s : The static pressure difference between the water level of the suction tank and the assembly tank. Where the amount of static pressure is variable due to the change of the water level of the source (river) and two values of static pressure can be calculated, one represents the upper value of the haed ($H_{s_{max}}$) and the other the minimum value of haed ($H_{s_{min}}$), and calculated by the difference between the water level of the water reservoir and the water level of the water source. It can also be calculated through,[5]:

$$H_s = H_{s_{RT}} - H_{s_{RES}} \dots\dots\dots (5)$$

And $H_{s_{max}} = H_{s_{RT}} - H_{s_{RES_{lower}}}$

$$H_{s_{min}} = H_{s_{RT}} - H_{s_{RES_{upper}}} \dots\dots\dots (6)$$

Where: $H_{s_{RES_{lower}}}$ = Lowest value for water level at (river).

$H_{s_{RES_{upper}}}$ = Highest water level value at (river).

The dynamic pressure of the system, which is generated by friction between the water and the pipes, can be calculated through the following equation, [4-5]:

$$H_d = \frac{K \times v^2}{2 \times g} \dots\dots\dots (7)$$

Where: v = water speed in pipes (m/s)

$$v = \frac{Q}{A} \dots\dots\dots (8)$$

$$A = \frac{\pi}{4} d^2 \dots\dots\dots (9)$$

k = The total loss factor of the system, which consists of two main parts, The first part represents the losses resulting from the $K_{fittings}$ inverse, valves, resin blockers and the links that bind the pipes together and others. The second part of the total loss factor is the losses resulting from the pipe network (K_{pipe}). The total loss factor of the System (K) =represents the total losses for the connecting extensions and the losses for the pipes, and is calculated by the following equation,[6]

$$K = K_{fittings} + K_{pipe} \dots\dots\dots (10)$$

The $K_{fittings}$ vary in quantity depending on the type of metal and the shape of the connecting accessories and the manufacturer of these accessories where the amount is processed by the manufacturer of each part. Table (1) is a model of $K_{fittings}$ values for the connecting accessories for iron pipes.

Table.1 $K_{fittings}$ for iron

Fitting Items	K fittings Value
Pipe inlet	0.05
45° Bend (short radius)	0.3
90° Bend (short radius)	0.75
Butterfly Valve (Fully Open)	0.3
Non-Return Valve	1
Pipe Outlet	0.2

K_{pipe} = Total losses for only straight tubes in the system, where it is calculated through , [6]

$$K_{Pipe} = \frac{f \times L}{d} \dots\dots\dots (11)$$

Where: L =Total lengths of straight pipes used in the system.

f = The friction coefficient of the pipe sand is calculated through:

$$f = \frac{0.25}{\left(\log\left(\frac{k_r}{3.7 \times d} + \frac{5.74}{Re^{0.9}}\right)\right)^2} \dots\dots\dots (12)$$

k_r : Represents the roughness factor of the pipe and depends on the type of pipe and the manufacturer of the pipe in addition to the internal conditions of the surface of the pipe in the condition that it is painted or not coated ..Etc. k_r values are based on the pipe manufacturer.

Re : Reynolds Number represents fluids, an amount that is not dimensional associated with smooth flow of water and the rate of energy absorbed by water during its flow, and for any fluid flow through a particular pipe and calculated through,[7]:

$$Re = \frac{v \times d}{\nu} \dots\dots\dots (13)$$

Where: ν = Viscosity = $1.31 \times 10^{-6} \frac{m^2}{s}$

The roughness coefficient of the k_r pipes, which depends on the type of metal used and made of the pipe and the amount of smoothness of the inner pipe surface, is measured in meters (m).

B. SELECTION OF PUMP SPEED

After the capacity of the pump used has been determined, the necessary speed should be determined to operate the pump to provide the necessary amount of water to be equipped in the case of changing levels of the suction (river). It represents the optimum speed of the pump that gives the necessary amount of water without additional losses to the system and at the lowest possible cava ratios to the system. The speed of the pump's rotation can be determined by drawing the hydraulic curve of the pump based on the approach law by taking different values of pump speed and drawing it with the height of the river level of the upper and lower cases. The intersection of the river level curve (in the upper and lower cases) with the amount of pumping required represents the amount of speed that this quantity provides. The law of approach and the drawing of the hydraulic curves of the pump can be applied as follows,[8]:

$$Q_1 / Q_2 = N_1 / N_2 \dots\dots\dots (14)$$

The N_1 and N_2 represent the rotational velocity of the pump shaft (r.p.m.) for the pumping amount Q_1, Q_2 , respectively. By applying the relationship of the discharge with the head, the equation (14) can be reformulated as follows:

$$H_1 / H_2 = N_1^2 / N_2^2 \dots\dots\dots (15)$$

H_1 and H_2 represent the head for discharge Q_1 and Q_2 , respectively.

To clarify the method of select the appropriate speed of the pump for several levels of river level, a model of the pump was studied with several speed and several pump quantities and the hydraulic curves of the pump were drawn and illustrated how to choose the amount of pump with the appropriate speed to provide it at the highest and least valuable to the river level, As shown in Fig. 2. At the pumping amount ($700 \text{ m}^3/\text{h}$), the rotary speed of the pump must be at the lowest level of the river level (BWL) at the limit of 675 rpm., while the rotational speed required to provide the amount of pump required at the highest level of the river level (TWL) should be in the range of (590 rpm). Disclaimer: If used Pipes containing intake or sudden expansion during the flow of water or the use of pipes with a non-circular section or other things that is not found in the system that has been explained should be introduced additional loss coefficients for these matters.

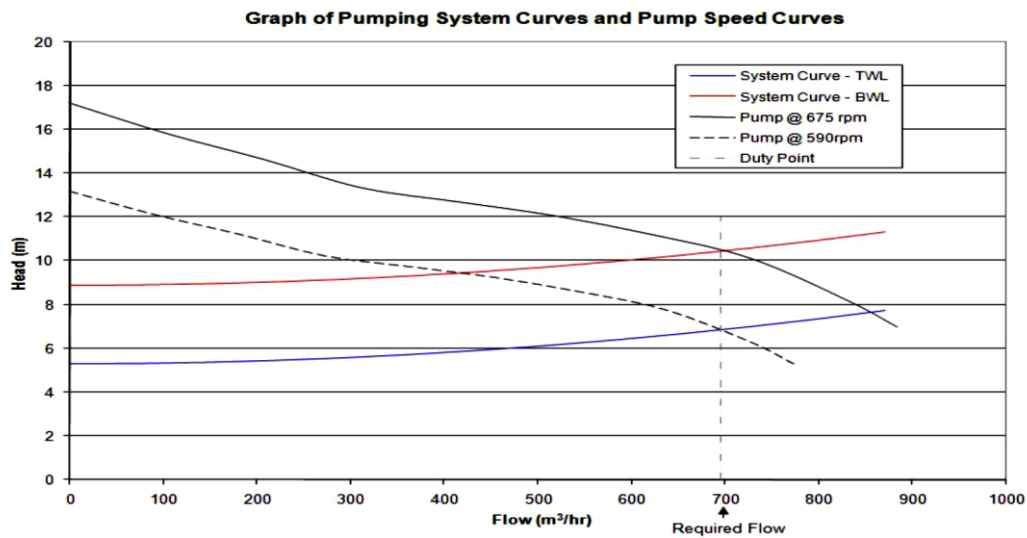


Fig. 2. Pump and Speed Curves

C. METHOD OF CALCULATION TO STUDY ANY PUMPING PROJECT

to study the project is determined the amount of water needed and determine the highest and lowest value of the water level of the river that passes during the year in addition to determining the distance between the river and the draw station and determining the quantity and type of connecting parts used in the station, as described in figure 2. The variables mentioned can be listed and the capacity required for the suction pump can be calculated through equation (2) as follows:

1. The amount of water to be withdrawn from the river, for example, 200 m³/h, and to ensure the amount of water required, we add up to (10%) of the water. The total amount of water required is thus limited to 220 m³/h. The excess water will return to the river by providing a return stream from the assembly tank to the river, Q in equation (9),[9].
2. The loss rate of static and dynamic head (H), equation (4), is then calculated by calculating losses for static and dynamic head as follows [10]:
 - a. To study the losses of static head, equation (5-6) the highest -difference between the water level in the assembly tank and the lowest water level in the river ($H_{s \max}$) which is within 7 m is studied. The lowest difference between the water level of the assembly tank and the highest level of the river level ($H_{s \min}$), which is within 4 m. equation (6) .We use the highest difference between the water levels to design the required set, which represents ($H_{s \max}=7$ m) which represents the static head of the system, equation (5), as shown in figure (2)
 - b. The loss factor for dynamic head (H_d), should then be calculated by equation 7, by calculating the speed rate of flow of water inside the pipes and calculating the value of the total loss factor (K). Speed and loss factor can be calculated as follows:
 - i. To calculate the amount of flow, the diameter used for the pipes must be determined, as pipes made of stainless steel material were used in an internal diameter (10") equivalent (0.254 m) and thus by studying the amount of water required and the diameter of the pipe used, the water speed can be determined, equation (8-9) where the speed flow (1.2 m/s).
 - ii. To calculate the total loss factor (K), equation (10), you must calculate the pipe loss factor (K_{pipe}) and the losses in the fittings (K_{fittings}), part of which is shown in Fig. 3. The loss factor for fittings can be calculated by calculating the total losses for each part of the system and using Table (1), the total value of the loss coefficient, as described in Table (2), can be found for the various fittings used.

Table 2. Calculating the Total Loss Factor for $K_{fittings}$

Fitting Items	K fittings Value	No. of Items	Item Total
Pipe inlet	0.05	1	0.05
45° Bend (short radius)	0.3	2	0.6
90° Bend (short radius)	0.75	8	6
Butterfly Valve (Fully Open)	0.3	3	0.9
Non Return Valve	1	1	1
Pipe Outlet	0.2	2	0.4
Total $K_{fittings}$			8.95

Then, using equation (11), the losses coefficient of the pipes (K_{pipe}) can be calculated, where the length of pipe used in the system must first be calculated, from the beginning of the lowest river level to the mouth of the water collection reservoir. It was found that the total length used in the system (46 m). And use equation (12) the friction coefficient of the pipes can be extracted by using the highest value of the roughness factor for stainless steel pipes used at a value of (0.3 mm=0.0003 m), and the $Re=232.67 \times 10^3$, equation (12), the friction coefficient of the pipes (f) can be calculated in the range of 0.0218. Thus, can be compensated for the calculation of the values, equation (12-13) of the pipe loss factor (K_{pipe}) of 3.94. After you can calculate the total loss factor by collecting the losses of the fittings and the losses of the pipes, by applying the equation (4) and using the highest value of static head and combining it with dynamic head, the maximum value of total head losses is calculated at the lowest level of the river level. From the information shown above, the highest value of head losses (static and dynamic) was found to be (7.95) m higher.

- Using pump efficiency ranging from (75% to 90%) Equation (2) can calculate the amount of capacity needed for the pump. To ensure the pump's delivery at the worst pump efficiency, we use the minimum pump efficiency value (75%) Thus, by applying equation (2) and the information calculated through equation (4), the pump suitable for pumping a quantity of water by (200 m³/h) is approximately 6.5 kW. To ensure the provision of pumping, a pump with a capacity of 10 kW can be used, with an additional pump safety factor of 1.5.

D. DESIGN OF FLOATING PUMPING STATION USING SUBMERSIBLE PUMP

Parts of the Pumping Station

It is considered one of the solutions to the reduction in water levels in the Iraqi rivers Fig. (3). Parts used in the design of the floating pumping station:

- Metal rafts (water-wings) qty. (4).
- A base of metal designed so that it has the ability to carry a huge submersible pumps qty. one or two as needed, and this welding base is coated with epoxy material 3 stages ((base layer, middle layer and final layer)) anti-oxidize and moisture.
- Submersible pump.
- Metal connections qty. (4).
- Chain link qty. (2).
- Flexible pipe qty. (1).
- Electric board cabin and accessories.
- Fixed connecting pipe connect with the tank.

The Mechanism of the Work of the Floating Pumping Station:

The submersible pump connects one or two as needed and prefers the specifications of the 8-ang discharged $Q=400$ (m³ / hr) and head (H=50m) The pump is floating and chained to avoid drifting, the flexible pipe allows the pump to descend with low water level, and the pump is electrically attached with high precision protection.

The Estimated Cost

The estimated cost is about \$25,000 with a single submersible pump.

Recommendations for the Floating Pumping Station

- We recommend that the government agencies concerned provide the material resources for the manufacture of such floating pumping stations or adopt the subject of their manufacture with the available capabilities and according to the attached chart.
- Researchers recommend conducting research that evaluates the performance of the submersible pumps and its calculations in terms of the methods and pressures to determine the size and quantity of them.

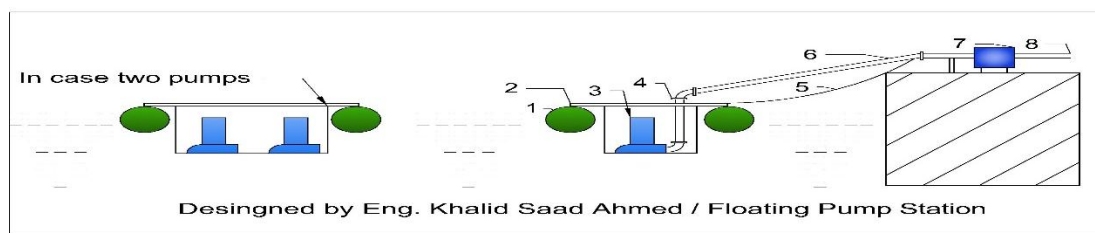


Fig. 3. Design and Components of a Floating Pumping Station

III. Result and Discussion

The exact calculation of the main height of the upper and lower limit is very important for the selection of the appropriate pump. When choosing an inappropriate pump, it increases or decreases the amount of water flow. For example, very little water leads to citizens not having access to drinking water and the increase in water may lead to waste in water and energy, and there are several factors affecting the operating pressure such as high river level and therefore all operating conditions must be assessed to ensure the ability of the pump to achieve what is required, and the use of variable speed pumps is one way to address the difference in operating pressure of the system. After the study was presented, it was shown that.

1. The important factors to focus on by choosing the right pump are the difference in the water level rise between the assembly tanks to the water level of the river, where the existing losses are nearly seven times the losses caused by horizontal flow in the pipes.
2. In addition, it was found that the quality of the metal used in the pipe industry has a clear effect through the roughness of the inner surface of the pipe where the losses decrease by increasing the smoothness of the surface and thus reducing the amount of capacity required for the pump required. Plastic pipes are therefore more effective in use (in terms of friction losses or operating pressure losses) in water projects. Note that metal pipes are more resistant to internal pressures than plastic pipes.
3. Furthermore, the connecting attachments are one of the most effective parts in generating significant losses to the pump's capacity during the flow of water in the pipes (loss of operating pressure) so it is recommended to use the smallest possible number of connecting attachments in the system.
4. Metal pipes are one of the most edible pipes over time, so impurities will be generated on the inner surface of the pipe, resulting in increased roughness of the surface and thus increased losses of operating power, resulting in a decrease in pump portability to generate the amount of water required over time. Therefore, these matters should be taken into consideration when designing the required pumps and this can be achieved using an appropriate safety factor.
5. The study provided shows that the amount of water required generates a disruptive flow within the pipes and thus leads to increased losses in the system, i.e. increasing the speed of flow of water within the pipes leads to increased losses in dynamic pressure and thus increased losses in the system. Therefore, increased power for the pump increases the speed of water and thus increases losses, which means a decrease in the amount of water processed by the project.
6. In the case of equipping the project with a pump with a high rotational speed, it is important in this case to reduce the speed of flow of water inside the pipes by increasing the diameters of the pipes used, which leads to a decrease in the speed of water and thus a decrease in the dynamic losses generated, which leads to an increase in the amount of water processed by the same pump used.
7. In addition, it was noted that increasing the length of the pipes used leads to increased losses, which means increasing the capacity needed for the pump, so it is recommended to install the water project at the nearest point of the river, i.e. at the lowest possible distance of the river, i.e. the lowest length of the pipes used.

Conclusion

In summary, we would like to show that the processing of a high-capacity pump does not mean the processing of a high amount of water due to the generation of losses of flow that reduces the amount of water processed. A higher amount of water can be equipped with a pump with a lower capacity by changing the internal system of the connection, which is the type and length of the pipes used, the type and number of connecting

accessories, in addition to changing the countries used for the pipes to generate the least possible losses to the system.

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