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HOW TO INCREASE THE CAPACITY OF AN EXISTING SEA WATER INTAKE

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ABSTRACT

Sea Water Intakes supplying water for desalination, cooling systems, or other parts of many important industrial components, such as refineries, and power plants are usually built in the shore lines and close to the target systems. In some conditions, such as expansion of the refinery, or other plants and in order to avoid building a new sea water intake because of lack of the suitable land or expending a lot of money, it is required to enhance the amount of withdrawing water and increase the capacity of the existing sea water intake. In such conditions, several important factors such as, minimum required submergence depth for the pumps, maximum allowed current velocity at the entry of the suction chambers, maximum allowed current velocity inside the intake and near the filters, and the flow pattern should be checked.

In this paper, it is tried to describe these factors and restrictions. In addition, a case study sea water intake located in South Pars Gas Field at the northern shore line of the Persian Gulf in the province of Boushehr, Iran, is considered and the mentioned factors and restrictions for increasing the capacity of sea water intake from 25,000 to 35,000 is discussed. Besides, a hydraulic mathematical model has been used to check the flow line of the developed system. At the end the results are discussed

Keywords: Sea Water Intake, Hydraulic model

INTRODUCTION

Sea water Intakes which are usually built in the areas close to sea waters are used for the cooling systems of many important industrial components such as refineries and power plants. In some cases an expansion of a built sea water intake will be required due to expansion of the relevant industrial component or a plan for building a new plant.

Therefore, this expansion is not because of that the existing power plant has not been designed and constructed properly but it is for the reason of new development on condition that there is no proper space to build another intake or the available space is too far from the refinery. As a result, we have to extract more amount of water than the designed discharge through the existing intake. In this situation, being sure about the feasibility of increasing the capacity of the intake, several important factors should be checked and some restrictions should be considered.

In this paper, these parameters and their importance are discussed. Also, the dominant limitations are presented. Then, relative parameters which should be checked not to violate the precise ranges determined by the limitations are introduced. After that discussions on Southern Pars Sea Water Intake located in Assalouyeh in south of Iran as a real case study whose discharge is to be increased are given. At the end, important statements are highlighted as a conclusion.

NOMENCLATURE

D:	Diameter of the pipe
L:	Length of the pipe
Q:	Discharge
h_b :	Bend head loss
h_{en} :	Entrance head loss
h_{ex} :	Exit head loss
h_f :	Friction head loss
h_T :	control valve head loss
h_{total} :	Total head loss
k_b :	Bend loss factor
k_{en} :	Entrance loss factor
k_{ex} :	Exit loss factor
k_T :	Discharge of each pipe
V_1:	Each pipe's current velocity

SEA WATER INTAKE DESIGN PARAMETERS

The main structure of a sea water intake consists of the geometry of the basin, the sea water supplier pipes, suction pumps, and other related equipments for extracting water from the sea. In some parts of the basin, the specifications of the equipments such as pumps and filters influence the geometry of the basin. However, the geometry in some cases dictates what kind of equipments can be used. This means that geometry and equipments should be seen together as they are closely dependent.

Supplier pipes convey the water from the sea to the basin. Then, the sea water is conducted to the suction pumps basin through a number of bays. Meanwhile, the water is filtered by passing through two sets of filters. Primary filters and secondary filters which are used to remove coarse and fine suspended materials from water respectively. Otherwise, these materials will damage suction pumps and other mechanical equipments. Afterward, the filtered water flows into a basin in which suction pumps are installed. Finally, sea water is pumped to the refinery or power plant. The suction pumps must be submerged in a certain depth of water to avoid the formation of vortex currents around their entrance which leads to suction of air into the pumps and causes disorderly operation of the pumps. This depth is determined by the pumps' manufacturer company. It should be considered that taking the greater amount of water from the intake decreases the depth of water near pumps. Therefore, cares must be taken to ensure the minimum required depth of water is always available in the vicinity of the pumps.

If sea water goes to sea water intake gravitationally - this is usual- therefore, the variation of sea water level due to tides and storms should be considered. It should be noted that the variation of water level inside the sea water intake and in the vicinity of the pumps depends strongly on the variation of sea water level.

Another factor which can influence the water level inside the sea water intake is the head loss of the flow through the pipes which normally are several hundreds meters long. In addition, they usually have rough surfaces or during the operation due to marine growth their surfaces will become rough. Also, the head loss due to valves, bends and other equipments should be considered.

When the sea water passes through several filters installed inside the water intake another head loss will occur. This head loss depends on the mesh size, material and the alignment of the filter. Meanwhile, if the filter doesn't be cleaned regularly it is expected to have more head loss as the mesh size of the filter become smaller due to holding suspended materials passing trough it.

The velocity of the water in various part of the sea water intake particularly in the vicinity of the entrance chamber, through the sea pipelines, in adjacent to the filters and near the pumps is another crucial factor which must be considered. It should be born in mind that the maximum velocity of sea water in various part of sea water intake should not exceed a specific figure and if the discharge of an existing sea water intake is increased these limitations should be checked to ensure the water velocity is still under control. For example according to [1] the water velocity at the entrance of the sea pipes should be less than 0.4 m/s. This is because of avoiding any suction of marine habitants and suspension materials getting into the pipes which can damage the small marine habitants as well as the sea water equipments. However, there are other methods such as chloride injection to kill the small marine habitants before getting trough the sea water intake.

It is common to have two set of filters; primary and secondary filters; inside the water intake. It is obvious that the current velocity next to each filter should be inline the manufactures' guidelines.

The other issue which is important is the location of the pumps and their distance from each other. Moreover, it is important that any vortex should not form in the current's pattern around the pumps.

STEPS SHOULD BE TAKEN FOR THE EXPANSION

It is important to know what steps one should take to study the expansion of an existing sea water intake. It should be noted that expansion of an existing sea water intake means any increase to the existing discharge capacity of sea water intake. Once the new discharge is known it is necessary to go through all of the design parameters described in the previous section quickly. Then the following steps should be done carefully

1- First of all, it should be specified how much the existing discharge capacity of the existing sea water intake is going to be increased. Find out the percentage of the increase. If it is around 20 to 30 percent of the existing discharge then other steps can be done. Other wise, if the existing discharge is going to be increased more than 30 percent it seems very hard to find an economic solution.

2- Estimate the capacity and number of the pumps which have to be added to the existing sea water intake in order to meet the new discharge demand. It is sometime better to use the same pump specifications existed there because of ease of maintenance and operation although in some cases this is not feasible as the manufacturer doesn't produce such a pump. In this case care should be taken to consider the selection of the new pumps in a way which doesn't make a significant influence on the operation of the existing pumps. For example if the minimum submerged depth of the existing water pumps is around 3.0 m therefore, the minimum of the submerged depth of the new pumps should be around 3.0 m as well. Otherwise, if the new pumps are selected with the minimum submerged water depth less than the existing ones, e.g. 2.0 m, then in the practice the new pumps have more safety factors than the others and if the water levels drops below 3.0 m the existing pumps will go out of operation however, the new ones will operate.

3- Check the geometry of the existing sea water intake to find out any available space for the new pumps. Consider all of the restrictions in the site and the positions of existing filters, pumps and cranes, pipelines and any superstructures built at top of the basin. It is obvious that the new pump spaces should be behind the secondary filters and should be far enough from the existing pumps to avoid any vortices around the pumps. It is better to place the new pumps in a way to keep the symmetry of the existing flow patterns.

4- In most of cases the expansion should be done while the water intake is under operation. Therefore, it is necessary to think about the method of construction during the expansion study.

5- In this stage, prepare various alternatives based on the above initial study. Then, compare them by using the most important factors including technical factors, operational considerations, available budget, construction time restriction and any other limitations defined by the client. It is better to weigh each factor in order to select the best alternative.

6- At this stage a hydraulic model of the selected alternative should be studied. In some cases, both mathematical and physical models are recommended. This model should give the designers, the variation of water level, current velocity and flow pattern inside the sea pipelines as well as water intake and pumps' basins.

7- The current velocity at the entrance of the sea pipelines should be checked. If it is more than the standards, some modifications should be done either to reduce the current velocity e.g. by adding another pipeline to the existing ones or treat the water quality to meet the environmental conditions by injecting chloride into the sea pipelines. In addition, the current velocity near the filters should be checked and compared with the instructions given by the manufactures. In the case of the discrepancies new filters should be designed or some modifications to the existing filters should be suggested.

8- It is important to check the current patterns near the new pumps to check whether the minimum water depth in the worst case will fulfill the requirements specified by the manufactures to ensure effective operation. Otherwise, the location of the pumps should be changed. If this is not available, the discharge demand should be reduced to fulfill the requirements.

9- Once, all of the above issues are checked and controlled, the final plan of the selected alternative can be issued. In this stage the basic design can be done by considering the operational restrictions.

CASE STUDY

Southern Pars sea water intake with the existing capacity of 25,000 m^3/hr (as shown in Figure 1), which is located in Assaluyeh in south of Iran, was built to supply water for the cooling systems of 8 phases of the Pars Complex Refineries. Sea water conducted to the basin due to gravity force through 4 pipes (one pipe spare), and then to the refinery phases via several pumps installed at the end of the basin. The pipes are made from steel and the internal side of them is covered by a concrete layer. The internal diameter of the pipes is 1.35 m and their length is 750 m. These pips have been laid on the bottom of the sea at the depth of 10 m from water surface elevation at Lowest Astronomical Tide (L.A.T).

Figure 2 demonstrates the position of intake, the pipes and the outfall channel, which returns the warm water from the refineries to the sea.

Figure 1: The location of South Pars Water Intake

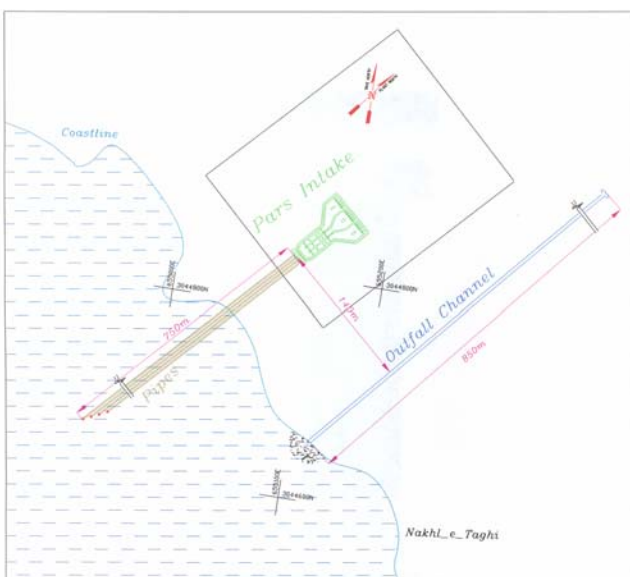

Figure 2: Southern Pars sea water intake and the position of the pipes and the outfall channel

Figure 3 illustrates the profile of the basin and the position of the pipes in the sea bottom. As shown in this figure, elevation of the bottom of the basin is -5.2 m from L.A.T. Consequently, sea water conveyed to the basin via pipes due to the gravity force.

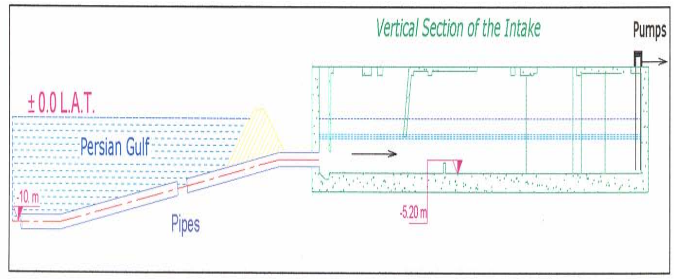

Figure 3: Profile of the basin and pipes

The geometry of the sea water intake Basin and the position of pumps in it are shown in Figure 4. As shown, different parts of the basin have been separated via several stop logs in order to provide future maintenance operations.

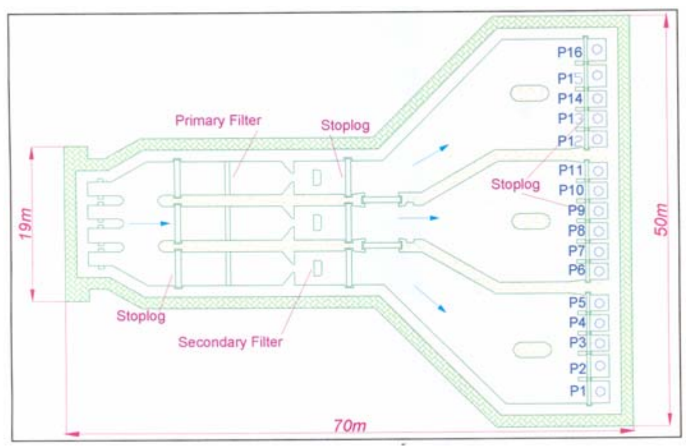

Figure 4: Plan of the intake and the position of pumps

The client intends to increase the capacity of the intake up to 31,000 m^3/hr in order to provide cooling water for the two other refineries (phases 9 & 10) not included in the existing ones. It is obvious that new pumps have to be added somewhere inside the intake to meet the new requirements. According to the initial study and some restrictions it is found that the only available free space in the basin is the inclined wall next to the pumps P1 to P5 as shown in Figure 5.

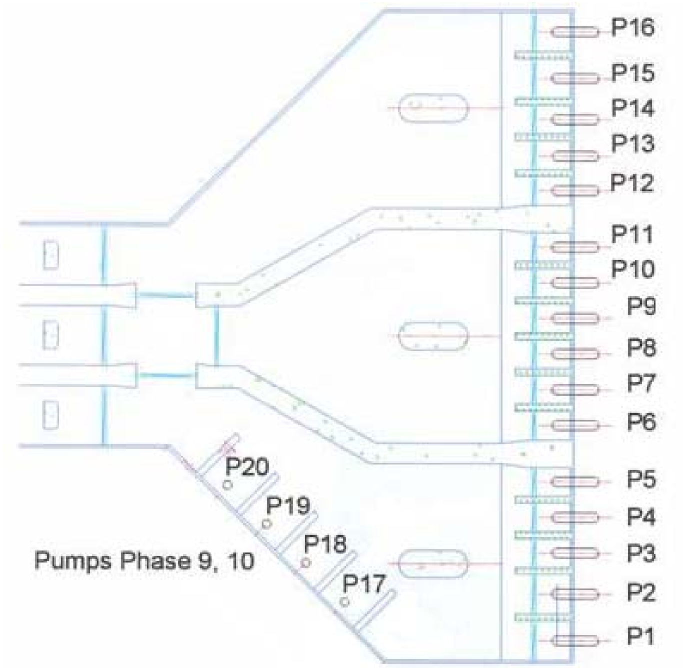

Figure 5: The location of new pumps in the sea water intake

Then, based on the new discharge, the head losses of the pipes are calculated and the results are summarized in Table 1. In this table "Q" is the amount of sea water discharge, "D" represents the pipes' diameter, "L" is the length of pipes, Q_1, V_1, $h_f, h_{en}, h_b, h_T, h_{ex}$, and h_{total} are each pipe's discharge, current velocity, Friction head loss, Entrance head loss, Bend head loss, control valve head loss, exit head loss, and cumulative head loss respectively. Manning number "n" is considered to be equal to 0.013, and the factors of losses are taken as below:

$$k_{en} = 0.1, k_b = 0.24, k_T = 0.64, k_{ex} = 1.$$

Table 1: The calculation of the pipes' head losses

No.	No. of pipes	Q_{total} (m^3/hr)	L (m)	D (m)	Q_1 (m^3/s)	V_1 (m/s)	h_f (m)	h_{en} (m)	h_{ex} (m)	h_b (m)	h_T (m)	h_{ex} (m)	h_{total} (m)
1	3	25000	750	1.35	2.31	1.62	1.411	0.013	0.120	0.032	0.065	0.133	1.77
2	4	25000	750	1.35	1.74	1.21	0.794	0.007	0.067	0.018	0.021	0.075	0.98

It can also be found from Table 1 that how the head loss varies with regard to the usage of different numbers of water supplying pipes. Likewise, the variation of the discharge of water causes the variation of the total head loss. The same calculations have been accomplished for the new discharge of 31000 m^3/hr and it is found that the total head losses are 1.55 m and 2.8 m for the usage of 4 and 3 pipes respectively. This information is used to determine the initial conditions and boundary conditions of the hydraulic mathematical model which is used to model the characteristics of the current within the basin. In fact, sea water level at the entrance of the sea pipes minus the total head losses is used as the initial condition for the sea water intake. The flux of incoming water current to the basin in various environmental situations at the end of pipes is used as boundary conditions of the model. In this two dimensional model, the ADI scheme is utilized which is second order both in time and space [3]. The model is calibrated using the results of a physical model studied by [2] for the same geometry water intake. The model was run for 2 conditions; usage of 3 or 4 numbers of water supplying pipes to convey the sea water from the sea to the basin. In each case, the model was run until the stable hydraulic conditions were achieved [4]. A sample of the model results is shown in the Figure 6.

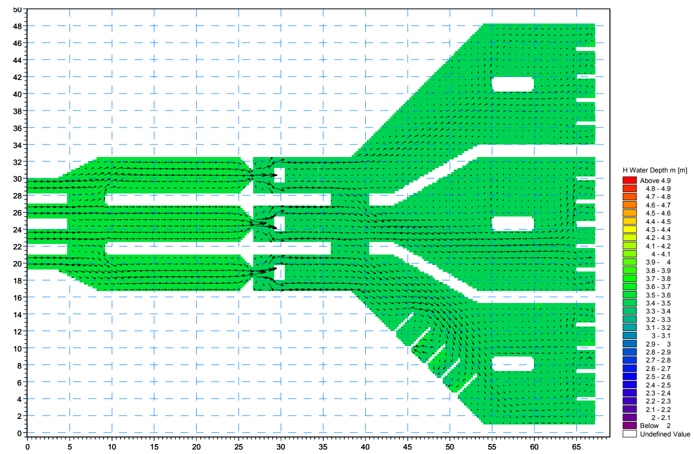

Figure 6: A sample of model results

Results of the model are summarized in Table 2.

Table 2: Summery of model results

No. of pipes	Total head loss (m)	Water surface elevation relating to the bottom of the basin (m)		
		At the sea	At the entrance of the basin	Near the pumps
3	2.76	5.2	2.44	2.1
4	1.55	5.2	3.65	3.4
permitted values	-	-	>2	>2.8

In this case study, the minimum submerged water depth near the pumps based on the manufactures' instruction is at least 2.8 m.

The results show that in the case of using of 4 numbers of sea water supplying pipes, the desired parameters remain at the permitted values, but, while 3 pipes are used, these limitations are not satisfied. Therefore, in the operation plan of the Intake, the maintenance of the spare pipe should be done when the minimum discharge is demanded. In other words, it is not recommended to use 3 pipelines when the water intake is under the maximum capacity operation as this may influence the refineries operation.

CONCLUSION

In this paper the design parameters which should be considered for the design of a sea water intake have been reviewed. Furthermore, necessary steps which should be taken for any possible expansion study have been highlighted. Then, the mentioned steps have been implemented for the South Pars water intake as a case study. It can be concluded that an existing sea water intake can be developed further to provide more water discharge, although the rate of expansion is restricted to 20 to 30 percent of the existing intake discharge. In such cases because of complexity of the problem and hydraulic behavior of the expanded water intake, it has been strongly recommended to apply both mathematical and physical hydraulic models. Mathematical hydraulic models can only been used if a general physical model is available or there are enough data to calibrate and validate the mathematical model.

It has been also shown in the case study that however, the expansion of sea water intake was successful but by applying the expansion more care must be taken during the maintenance period as it not possible to close down one of the pipes during the peak situation which the maximum discharge demand is required and the worst scenario environmental situation is occurred.

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